(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 965 872 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
28.09.2022 Bulletin 2022/39

(21) Application number: **14196474.2**

(22) Date of filing: **05.12.2014**

(51) International Patent Classification (IPC):
B25J 5/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B21J 15/02; B21J 15/10; B21J 15/142; B25J 5/007; B25J 11/007; B60G 3/145; B64F 5/10; B29C 2793/0081; B60G 2204/143; B60G 2204/418; B60G 2206/8207; B60G 2300/60; Y02P 90/80; Y02T 50/40

(54) **Mobile platforms for performing operations inside a fuselage assembly**

Mobile Plattformen zur Durchführung von Verfahren im Innern einer Rumpfanordnung

Plateformes mobiles permettant d'effectuer des opérations à l'intérieur d'un ensemble de fuselage

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **09.07.2014 US 201462022641 P**

(43) Date of publication of application:
13.01.2016 Bulletin 2016/02

(73) Proprietor: **The Boeing Company**
Chicago, IL 60606-1596 (US)

(72) Inventors:
- **Oberoi, Harinder S.**
  Chicago IL 60606-2016 (US)
- **Reese, Richard Griffith, IV**
  Chicago IL 60606-2016 (US)
- **Barrick, Kevin Marion**
  Chicago IL 60606-2016 (US)
- **Do, Quang T.**
  Chicago IL 60606-2016 (US)
- **Draper, Alan**
  Chicago IL 60606-2016 (US)
- **Miller, Jeffrey Lawrence**
  Chicago IL 60606-2016 (US)
- **Gudzinski, Gregory**
  Chicago IL 60606-2016 (US)

(74) Representative: **Boult Wade Tennant LLP**
Salisbury Square House
8 Salisbury Square
London EC4Y 8AP (GB)

(56) References cited:
EP-A1- 2 617 536
US-A- 6 098 260
US-A1- 2012 300 093

EP 2 965 872 B1

Description

BACKGROUND

1. Field:

[0001] The present disclosure relates generally to aircraft and, in particular, to building the fuselage of an aircraft. Still more particularly, the present disclosure relates to a method, apparatus, and system for performing operations within the interior of a fuselage assembly using internal mobile platforms.

2. Background:

[0002] Building a fuselage may include assembling skin panels and a support structure for the fuselage. The skin panels and support structure may be joined together to form a fuselage assembly. For example, without limitation, the skin panels may have support members, such as stiffeners and stringers, attached to the surface of the skin panels that will face the interior of the fuselage assembly. These support members may be used to form the support structure for the fuselage. The skin panels may be positioned relative to each other and the support members may be tied together to form this support structure. Riveting operations may then be performed to join the skin panels and support members together to form the fuselage assembly. The fuselage assembly may be assembled in a manner that meets outer mold line (OML) requirements and inner mold line (IML) requirements for the fuselage assembly.

[0003] With some currently available methods for building a fuselage, the riveting operations performed to assemble the skin panels and the support members together to form the fuselage assembly may be performed manually. For example, without limitation, a first human operator positioned at an exterior of the fuselage assembly and a second human operator positioned at an interior of the fuselage assembly may use handheld tools to perform these riveting operations. In some cases, this type of manual riveting process may be more labor-intensive, time-consuming, ergonomically challenging, or expensive than desired. Further, some current assembly methods used to build fuselages that involve manual riveting processes may not allow fuselages to be built in the desired assembly facilities or factories at desired assembly rates or desired assembly costs.

[0004] In some cases, the current assembly methods and systems used to build fuselages may require that these fuselages be built in facilities or factories specifically designated and permanently configured for building fuselages. In some cases, these current assembly methods and systems may be unable to accommodate different types and shapes of fuselages. For example, without limitation, large and heavy equipment needed for building fuselages may be permanently affixed to a factory and configured for use solely with fuselages of a specific type.

[0005] Further, with some current assembly methods, performing operations, such as riveting operations, from within a fuselage may be more difficult, time-consuming, and ergonomically challenging for human operators than desired. Therefore, it would be desirable to have a method and apparatus that take into account at least some of the issues discussed above, as well as other possible issues.

[0006] US6098260, in accordance with its abstract, states: "a fastening assembly system for applying fasteners along the seams of a cylindrical structure. The fastening apparatus includes a base unit which releasably attaches to a cylindrical structure, and a first fastening device coupled the base unit for applying fasteners along a seam of the cylindrical structure. The base unit may be embodied as either two crescent shaped members in parallel alignment for attaching to the upper half of the cylindrical structure. Alternatively, the base unit may include a base plate that is attachable to the floor beams on the interior of the cylindrical structure. In the preferred embodiment, the first fastening device cooperate with a second fastening device located on the opposite side of the cylindrical structure during the fastening process".

[0007] US2012300093, in accordance with its abstract, states: "the system, composed of a mobile unit comprising a video camera, points automatically a plurality of predetermined locations inside a structure by a successive implementation of a first images recognition process and a second images recognition process by means of said video camera".

[0008] EP2617536, in accordance with its abstract, states: "A system includes a frame having spaced apart first and second upright members, and a robot including an end effector and a plurality of arms. The arms extend from the end effector and clamp onto the first and second frame members to position the end effector between the first and second frame members".

[0009] US2012/0237319, in accordance with its Abstract, states: "An operator controllable robotic device is disclosed. The robotic device comprises a support member, an upper robotic arm, a lower robotic arm, and a control arm. The upper robotic arm is coupled to the support member and has rotational movement in at least one degree of freedom relative to the support member. The lower robotic arm is coupled to the upper robotic arm and has rotational movement in at least one degree of freedom relative to the upper robotic arm. The control arm allows an operator to control the robotic device. The control arm is coupled to the upper robotic arm and has rotational movement in at least one degree of freedom relative to the upper robotic arm. The control arm allows a movement of the operator to control a movement of at least one of the upper robotic arm and the lower robotic arm."

SUMMARY

[0010] In summary, there is provided a method for performing an assembly operation, the method comprising: macro-positioning a tool within an interior of a fuselage assembly; micro-positioning the tool relative to a particular location on a panel of the fuselage assembly; and performing the assembly operation at the particular location on the panel using the tool, wherein: macro-positioning the tool comprises moving a platform base of an internal mobile platform carrying the tool with at least one degree of freedom relative to a floor inside the fuselage assembly; and wherein: a track system including a first track and a second track is associated with the platform base, the first and second tracks being for driving the internal mobile platform in a first direction; and the first and second tracks include a roller chain, a plurality of rollers, and a plurality of support plates.

[0011] Macro-positioning the tool may comprise: moving a platform base of an internal mobile platform carrying the tool with at least one degree of freedom relative to a floor inside the fuselage assembly.

[0012] Micro-positioning the tool may comprise: moving the tool with the at least one degree of freedom relative to the platform base.

[0013] Micro-positioning the tool may comprise: commanding at least one of an internal robotic device or a movement system associated with the internal mobile platform to move the tool with the at least one degree of freedom relative to the platform base to the particular location.

[0014] Macro-positioning the tool may comprise: driving an internal mobile platform carrying the tool across a floor within the interior of the fuselage assembly.

[0015] Driving the internal mobile platform may comprise: driving the internal mobile platform carrying the tool across the floor within the interior of the fuselage assembly to an internal position relative to the panel of the fuselage assembly.

[0016] Driving the internal mobile platform may comprise: driving the internal mobile platform across the floor inside the fuselage assembly using a track system.

[0017] Performing the assembly operation may comprise: performing a riveting operation at the particular location using the tool.

[0018] Performing the riveting operation comprises: performing the riveting operation at the particular location using a bucking bar.

[0019] Macro-positioning the tool may comprise: driving an internal mobile platform autonomously across a platform level of a tower onto a floor within the interior of the fuselage assembly and into a position relative to the panel.

[0020] The method may further comprise: receiving a number of utilities at the internal mobile platform through a number of utility cables extending from a cable management system associated with the tower.

[0021] Receiving the number of utilities may comprise: receiving the number of utilities at a set of units associated with a platform base of the internal mobile platform.

[0022] The method may further comprise: removably associating an end effector with an internal robotic device associated with an internal mobile platform.

[0023] The method may further comprise: removably associating the tool with the end effector.

[0024] There is also provided an apparatus comprising: a macro-positioning system associated with an internal mobile platform; and a micro-positioning system associated with the internal mobile platform, wherein the micro-positioning system comprises: a movement system for moving a tool with at least one degree of freedom relative to a platform base of the internal mobile platform; and wherein the macro-positioning device comprises: a platform movement system for moving a platform base of the internal mobile platform with at least one degree of freedom relative to a floor inside a fuselage assembly, wherein a track system including a first track and a second track is associated with the platform base, the first and second tracks being for driving the internal mobile platform in a first direction, the first and second tracks including a roller chain, a plurality of rollers, and a plurality of support plates.

[0025] The micro-positioning system may comprise at least one of an internal robotic device associated with the internal mobile platform or a movement system.

[0026] The apparatus further comprises: an internal robotic device associated with the internal mobile platform; and a tool associated with the internal robotic device.

[0027] The tool may be removably associated with an end effector; an internal riveting tool; or a bucking bar.

[0028] The internal mobile platform may comprise: a set of units connected to a number of utility cables that extend from a cable management system.

[0029] The number of utility cables may carry a number of utilities that include at least one of power, air, communications, water, or hydraulic fluid.

[0030] The apparatus may comprise: a first robotic device associated with the internal mobile platform, wherein a first internal tool is associated with the first robotic device.

[0031] The apparatus may further comprise: a second robotic device associated with the internal mobile platform, wherein a second internal tool is associated with the second robotic device.

[0032] The internal mobile platform may comprise: a platform base; and a number of robotic systems associated with the platform base.

[0033] The number of robotic systems may comprise: a first robotic system; and a second robotic system.

[0034] The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is an illustration of a manufacturing environment in the form of a block diagram in accordance with an illustrative embodiment;

Figure 2 is an illustration of a fuselage assembly in the form of a block diagram in accordance with an illustrative embodiment;

Figure 3 is an illustration of a plurality of mobile systems of a flexible manufacturing system within a manufacturing environment in the form of a block diagram in accordance with an illustrative embodiment;

Figure 4 is an illustration a plurality of mobile platforms in the form of a block diagram in accordance with an illustrative embodiment;

Figure 5 is an illustration of a flow of a number of utilities across a distributed utility network in the form of a block diagram in accordance with an illustrative embodiment;

Figure 6 is an illustration of an internal mobile platform in the form of a block diagram in accordance with an illustrative embodiment;

Figure 7 is an illustration of an isometric view of a manufacturing environment in accordance with an illustrative embodiment;

Figure 8 is an illustration of a first tower coupled to a utility fixture in accordance with an illustrative embodiment;

Figure 9 is an illustration of an isometric view of a cradle system in accordance with an illustrative embodiment;

Figure 10 is an illustration of an isometric view of an assembly fixture formed using a cradle system and coupled to a first tower in accordance with an illustrative embodiment;

Figure 11 is an illustration of an isometric view of one stage in the assembly process for building a fuselage assembly that is being supported by an assembly fixture in accordance with an illustrative embodiment;

Figure 12 is an illustration of an isometric view of another stage in the assembly process for building a fuselage assembly in accordance with an illustrative embodiment;

Figure 13 is an illustration of an isometric view of another stage in the assembly process for building a fuselage assembly being supported by an assembly fixture in accordance with an illustrative embodiment;

Figure 14 is an illustration of an isometric view of another stage in the assembly process for building a fuselage assembly in accordance with an illustrative embodiment;

Figure 15 is an illustration of an isometric view of a second tower coupled to a utility fixture and an assembly fixture supporting a fuselage assembly in accordance with an illustrative embodiment;

Figure 16 is an illustration of an isometric cutaway view of a plurality of mobile platforms performing fastening processes within an interior of a fuselage assembly in accordance with an illustrative embodiment;

Figure 17 is an illustration of a cross-sectional view of a flexible manufacturing system performing operations on a fuselage assembly in accordance with an illustrative embodiment;

Figure 18 is an illustration of an isometric view of a fully built fuselage assembly in accordance with an illustrative embodiment;

Figure 19 is an illustration of an isometric view of fuselage assemblies being built within a manufacturing environment in accordance with an illustrative embodiment;

Figure 20 is an illustration of a top isometric view of an internal mobile robot platform in accordance with an illustrative embodiment;

Figure 21 is an illustration of a bottom isometric view of an internal mobile platform in accordance with an illustrative embodiment;

Figure 22 is an illustration of an enlarged view of a track in accordance with an illustrative embodiment;

Figure 23 is an illustration of a side view of an internal mobile platform in accordance with an illustrative embodiment;

Figure 24 is an illustration of an internal mobile platform in accordance with an illustrative embodiment;

Figure 25 is an illustration of a bottom isometric view of an internal mobile platform in accordance with an illustrative embodiment;

Figure 26 is an illustration of a side view of an internal mobile platform in accordance with an illustrative embodiment;

Figure 27 is an illustration of an internal mobile platform moving inside a fuselage assembly in accordance with an illustrative embodiment;

Figure 28 is an illustration of a process for performing an assembly operation in the form of a flowchart in accordance with an illustrative embodiment;

Figure 29 is an illustration of a process for performing an assembly operation in the form of a flowchart in accordance with an illustrative embodiment;

Figure 30 is an illustration of a process for reducing point-loading by an internal mobile platform in the form of a flowchart in accordance with an illustrative embodiment;

Figure 31 is an illustration of a process for performing fastening operations in the form of a flowchart in accordance with an illustrative embodiment;

Figure 32 is an illustration of a process for performing fastening operations in the form of a flowchart in accordance with an illustrative embodiment;

Figure 33 is an illustration of a data processing system in the form of a block diagram in accordance with an illustrative embodiment;

Figure 34 is an illustration of an aircraft manufacturing and service method in the form of a block diagram in accordance with an illustrative embodiment; and

Figure 35 is an illustration of an aircraft in the form of a block diagram in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

[0036] The illustrative embodiments recognize and take into account different considerations. For example, the illustrative embodiments recognize and take into account that it may be desirable to automate the process of building a fuselage assembly for an aircraft. Automating the process of building a fuselage assembly for an aircraft may improve build efficiency, improve build quality, and reduce costs associated with building the fuselage assembly. The illustrative embodiments also recognize and take into account that automating the process of building a fuselage assembly may improve the accuracy and precision with which assembly operations are performed, thereby ensuring improved compliance with outer mold line (OML) requirements and inner mold line (IML) requirements for the fuselage assembly.

[0037] Further, the illustrative embodiments recognize and take into account that automating the process used to build a fuselage assembly for an aircraft may significantly reduce the amount of time needed for the build cycle. For example, without limitation, automating fastening operations may reduce and, in some cases, eliminate, the need for human operators to perform these fastening operations as well as other types of assembly operations.

[0038] Further, this type of automation of the process for building a fuselage assembly for an aircraft may be less labor-intensive, time-consuming, ergonomically challenging, and expensive than performing this process primarily manually. Reduced manual labor may have a desired benefit for the human laborer. Additionally, automating the fuselage assembly process may allow fuselage assemblies to be built in desired assembly facilities and factories at desired assembly rates and desired assembly costs.

[0039] The illustrative embodiments also recognize and take into account that it may be desirable to use equipment that can be autonomously driven and operated to automate the process of building a fuselage assembly. In particular, it may be desirable to have an autonomous flexible manufacturing system comprised of mobile systems that may be autonomously driven across a factory floor, autonomously positioned relative to the factory floor as needed for building the fuselage assembly, autonomously operated to build the fuselage assembly, and then autonomously driven away when building of the fuselage assembly has been completed.

[0040] As used herein, performing any operation, action, or step autonomously may mean performing that operation substantially without any human input. For example, without limitation, a platform that may be autonomously driven is a platform that may be driven substantially independently of any human input. In this manner, an autonomously drivable platform may be a platform that is capable of driving or being driven substantially independently of human input.

[0041] Thus, the illustrative embodiments provide a method, apparatus, and system for building a fuselage assembly for an aircraft. In particular, the illustrative embodiments provide an autonomous flexible manufacturing system that automates most, if not all, of the process of building a fuselage assembly. For example, without limitation, the autonomous flexible manufacturing system may automate the process of installing fasteners to join fuselage skin panels and a fuselage support structure together to build the fuselage assembly.

[0042] However, the illustrative embodiments recognize and take into account that automating the process for building a fuselage assembly using an autonomous flexible manufacturing system may present unique technical challenges that require unique technical solutions. For example, the illustrative embodiments recognize and take into account that it may be desirable to provide utilities to all of the various systems within the autonomous flexible manufacturing system. In particular, it may be desirable to provide these utilities in a manner that will not disrupt or delay the process of building the fuselage assembly or restrict the movement of various mobile systems within the autonomous flexible manufacturing system over a factory floor.

[0043] For example, without limitation, it may be desirable to provide a set of utilities, such as power, communications, and air, to the autonomous flexible manufacturing system using an infrastructure that includes only a single direct connection to each of a set of utility sources providing the set of utilities. These direct connections may be above-ground, in-ground, or embedded. These direct connections may be established using, for example, without limitation, a utility fixture. Thus, the infrastructure may include a utility fixture that provides a direct connection to each of the set of utility sources and an assembly area with a floor space sufficiently large to allow the various systems of an autonomous flexible manufacturing system to be coupled to the utility fixture and each other in series. In this manner, the set of utilities may flow from the set of utility sources to the utility fixture and then downstream to the various systems of the autonomous flexible manufacturing system within the assembly area.

[0044] Thus, the illustrative embodiments provide a distributed utility network that may be used to provide utilities to the various systems of the autonomous flexible manufacturing system. The distributed utility network may provide these utilities in a manner that does not restrict or impede movement of the various mobile systems of the autonomous flexible manufacturing system. The different mobile systems of the autonomous flexible manufacturing system may be autonomously coupled to each other to create this distributed utility network.

[0045] Further, the illustrative embodiments recognize and take into account that it may be desirable to have an apparatus and method for accessing an interior of a fuselage assembly easily and in a safe manner. The illustrative embodiments recognize and take into account that using a tower having a number of platform levels that can be mated with a number of floors of the fuselage assembly may improve the ease with which a human operator or mobile platforms comprising robotic devices may be moved into the interior of the fuselage assembly.

[0046] Referring now to the figures and, in particular, with reference to **Figures 1-6,** illustrations of a manufacturing environment are depicted in the form of block diagrams in accordance with an illustrative embodiment. In particular, in **Figures 1-6,** a fuselage assembly, a flexible manufacturing system, the various systems within the flexible manufacturing system that may be used to build the fuselage assembly, and a distributed utility network are described.

[0047] Turning now to **Figure 1,** an illustration of a manufacturing environment is depicted in the form of a block diagram in accordance with an illustrative embodiment. In this illustrative example, manufacturing environment **100** may be an example of one environment in which at least a portion of fuselage **102** may be manufactured for aircraft **104**.

[0048] Manufacturing environment **100** may take a number of different forms. For example, without limitation, manufacturing environment **100** may take the form of a factory, a manufacturing facility, an outdoor factory area, an enclosed manufacturing area, an offshore platform, or some other type of manufacturing environment **100** suitable for building at least a portion of fuselage **102.**

[0049] Fuselage **102** may be built using manufacturing process **108**. Flexible manufacturing system **106** may be used to implement at least a portion of manufacturing process **108**. In one illustrative example, manufacturing process **108** may be substantially automated using flexible manufacturing system **106**. In other illustrative examples, only one or more stages of manufacturing process **108** may be substantially automated.

[0050] Flexible manufacturing system **106** may be configured to perform at least a portion of manufacturing process **108** autonomously. In this manner, flexible manufacturing system **106** may be referred to as autonomous flexible manufacturing system **112**. In other illustrative examples, flexible manufacturing system **106** may be referred to as an automated flexible manufacturing system.

[0051] As depicted, manufacturing process **108** may include assembly process **110** for building fuselage assembly **114**. Flexible manufacturing system **106** may be configured to perform at least a portion of assembly process **110** autonomously.

[0052] Fuselage assembly **114** may be fuselage **102** at any stage during manufacturing process **108** prior to the completion of manufacturing process **108.** In some cases, fuselage assembly **114** may be used to refer to a partially assembled fuselage **102.** Depending on the implementation, one or more other components may need to be attached to fuselage assembly **114** to fully complete the assembly of fuselage **102.** In other cases, fuselage assembly **114** may be used to refer to the fully assembled fuselage **102.** Flexible manufacturing system **106** may build fuselage assembly **114** up to the point needed to move fuselage assembly **114** to a next stage in the manufacturing process for building aircraft **104.** In some cases, at least a portion of flexible manufacturing system **106** may be used at one or more later stages in the manufacturing process for building aircraft **104.**

[0053] In one illustrative example, fuselage assembly **114** may be an assembly for forming a particular section of fuselage **102.** As one example, fuselage assembly **114** may take the form of aft fuselage assembly **116** for forming an aft section of fuselage **102.** In another example, fuselage assembly **114** may take the form of forward fuselage assembly **117** for forming a forward section of fuselage **102.** In yet another example, fuselage assembly **114** may take the form of middle fuselage assembly **118** for forming a center section of fuselage **102** or some other middle section of fuselage **102** between the aft and forward sections of fuselage **102.**

[0054] As depicted, fuselage assembly **114** may include plurality of panels **120** and support structure **121.** Support structure **121** may be comprised of plurality of members **122.** Plurality of members **122** may be used to both support plurality of panels **120** and connect plurality of panels **120** to each other. Support structure **121** may help provide strength, stiffness, and load support for fuselage assembly **114.**

[0055] Plurality of members **122** may be associated with plurality of panels **120.** As used herein, when one component or structure is "associated" with another component or structure, the association is a physical association in the depicted examples.

[0056] For example, a first component, such as one of plurality of members **122,** may be considered to be associated with a second component, such as one of plurality of panels **120,** by being at least one of secured to the second component, bonded to the second component, mounted to the second component, attached to the component, coupled to the component, welded to the second component, fastened to the second component, adhered to the second component, glued to the second component, or connected to the second component in some other suitable manner. The first component also may be connected to the second component using one or more other components. For example, the first component may be connected to the second component using a third component. Further, the first component may be considered to be associated with the second component by being formed as part of the second component, an extension of the second component, or both. In another example, the first component may be considered part of the second component by being co-cured with the second component.

[0057] As used herein, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items may be used and only one of the items in the list may be needed. The item may be a particular object, thing, action, process, or category. In other words, "at least one of" means any combination of items or number of items may be used from the list, but not all of the items in the list may be required.

[0058] For example, "at least one of item A, item B, and item C" or "at least one of item A, item B, or item C" may mean item A; item A and item B; item B; item A, item B, and item C; or item B and item C. In some cases, "at least one of item A, item B, and item C" may mean, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; or some other suitable combination.

[0059] In these illustrative examples, a member of plurality of members **122** may be associated with at least one of plurality of panels **120** in a number of different ways. For example, without limitation, a member of plurality of members **122** may be attached directly to a single panel, attached to two or more panels, attached to another member that is directly attached to at least one panel, attached to at least one member that is directly or indirectly attached to at least one panel, or associated with at least one of plurality of panels **120** in some other way.

[0060] In one illustrative example, substantially all or all of plurality of members **122** may be associated with plurality of panels **120** prior to the beginning of assembly process **110** for building fuselage assembly **114.** For example, a corresponding portion of plurality of members **122** may be associated with each panel of plurality of panels **120** prior to plurality of panels **120** being joined to each other through assembly process **110.**

[0061] In another illustrative example, only a first portion of plurality of members **122** may be associated with plurality of panels **120** prior to the beginning of assembly process **110.** Assembly process **110** may include attaching a remaining portion of plurality of members **122** to plurality of panels **120** for at least one of providing support to plurality of panels **120** or connecting plurality of panels **120** together. The first portion of plurality of members **122** attached to plurality of panels **120** prior to assembly process **110** and the remaining portion of plurality of members **122** attached to plurality of panels **120** during assembly process **110** may together form support structure **121.**

[0062] In yet another illustrative example, all of plurality of members **122** may be associated with plurality of panels **120** during assembly process **110.** For example, each of plurality of panels **120** may be "naked" without any members attached to or otherwise associated with the panel prior to assembly process **110.** During assembly process **110,** plurality of members **122** may then be associated with plurality of panels **120.**

[0063] In this manner, support structure **121** for fuselage assembly **114** may be built up in a number of different ways. Fuselage assembly **114** comprising plurality of panels **120** and support structure **121** is described in greater detail in **Figure 2** below.

[0064] Building fuselage assembly **114** may include joining plurality of panels **120** together. Joining plurality of panels **120** may be performed in a number of different ways. Depending on the implementation, joining plurality of panels **120** together may include joining one or more of plurality of members **122** to one or more of plurality of panels **120** or to other members of plurality of members **122.**

[0065] In particular, joining plurality of panels **120** may include joining at least one panel to at least one other panel, joining at least one member to at least one other member, or joining at least one member to at least one panel, or some combination thereof. As one illustrative example, joining a first panel and a second panel together may include at least one of the following: fastening the first panel directly to the second panel, joining a first member associated with the first panel to a second member associated with the second panel, joining a member associated with the first panel directly to the second panel, joining one member associated with both the first panel and the second panel to another member, joining a selected member to both the first panel and the second panel, or some other type of joining operation.

[0066] Assembly process **110** may include operations **124** that may be performed to join plurality of panels **120** together to build fuselage assembly **114.** In this illustrative example, flexible manufacturing system **106** may be used to perform at least a portion of operations **124** autonomously.

[0067] Operations **124** may include, for example, but are not limited to, temporary connection operations **125,** drilling operations **126,** fastener insertion operations **128,** fastener installation operations **130,** inspection operations **132,** other types of assembly operations, or some combination thereof. Temporary connection operations **125** may be performed to temporarily connect plurality of panels **120** together. For example, without limitation, temporary connection operations **125** may include temporarily tacking plurality of panels **120** together using tack fasteners.

[0068] Drilling operations **126** may include drilling holes through one or more of plurality of panels **120** and, in some cases, through one or more of plurality of members **122.** Fastener insertion operations **128** may include inserting fasteners into the holes drilled by drilling operations **126.**

[0069] Fastener installation operations **130** may include fully installing each of the fasteners that have been inserted into the holes. Fastener installation operations **130** may include, for example, without limitation, riveting operations, interference-fit bolting operations, other types of fastener installation operations, or some combination thereof. Inspection operations **132** may include inspecting the fully installed fasteners. Depending on the implementation, flexible manufacturing system **106** may be used to perform any number of these different types of operations **124** substantially autonomously.

[0070] As depicted, flexible manufacturing system **106** may include plurality of mobile systems **134,** control system **136,** and utility system **138.** Each of plurality of mobile systems **134** may be a drivable mobile system. In some cases, each of plurality of mobile systems **134** may be an autonomously drivable mobile system. For example, without limitation, each of plurality of mobile systems **134** may include one or more components that may be autonomously driven within manufacturing environment **100** from one location to another location. Plurality of mobile systems **134** are described in greater detail in **Figure 3** below.

[0071] In this illustrative example, control system **136** may be used to control the operation of flexible manufacturing system **106.** For example, without limitation, control system **136** may be used to control plurality of mobile systems **134.** In particular, control system **136** may be used to direct the movement of each of plurality of mobile systems **134** within manufacturing environment **100.** Control system **136** may be at least partially associated with plurality of mobile systems **134.**

[0072] In one illustrative example, control system **136** may include set of controllers **140.** As used herein, a "set of" items may include one or more items. In this manner, set of controllers **140** may include one or more controllers.

[0073] Each of set of controllers **140** may be implemented using hardware, firmware, software, or some combination thereof. In one illustrative example, set of controllers **140** may be associated with plurality of mobile systems **134.** For example, without limitation, one or more of set of controllers **140** may be implemented as part of plurality of mobile systems **134.** In other examples, one or more of set of controllers **140** may be implemented independently of plurality of mobile systems **134.**

[0074] Set of controllers **140** may generate commands **142** to control the operation of plurality of mobile systems **134** of flexible manufacturing system **106.** Set of controllers **140** may communicate with plurality of mobile systems **134** using at least one of a wireless communications link, a wired communications link, an optical communications link, or other type of communications link. In this manner, any number of different types of communications links may be used for communication with and between set of controllers **140.**

[0075] In these illustrative examples, control system **136** may control the operation of plurality of mobile systems **134** using data **141** received from sensor system **133.** Sensor system **133** may be comprised of any number of individual sensor systems, sensor devices, controllers, other types of components, or combination thereof. In one illustrative example, sensor system **133** may include laser tracking system **135** and radar system **137.** Laser tracking system **135** may be comprised of any number of laser tracking devices, laser targets, or combination thereof. Radar system **137** may be comprised of any number of radar sensors, radar targets, or combination thereof.

[0076] Sensor system **133** may be used to coordinate the movement and operation of the various mobile systems in plurality of mobile systems **134** within manufacturing environment **100.** As one illustrative example, radar system **137** may be used for macro-positioning mobile systems, systems within mobile systems, components within mobile systems, or some combination thereof. Further, laser tracking system **135** may be used for micro-positioning mobile systems, systems within mobile systems, components within mobile systems, or some combination thereof.

[0077] Plurality of mobile systems **134** may be used to form distributed utility network **144.** Depending on the implementation, one or more of plurality of mobile systems **134** may form distributed utility network **144.** Number of utilities **146** may flow from number of utility sources **148** to the various mobile systems of plurality of mobile systems **134** that make up distributed utility network **144.**

[0078] In this illustrative example, each of number of utility sources **148** may be located with manufacturing environment **100.** In other illustrative examples, one or more of number of utility sources **148** may be located outside of manufacturing environment **100.** The corresponding utility provided by these one or more utility sources may then be carried into manufacturing environment **100** using, for example, without limitation, one or more utility cables.

[0079] In one illustrative example, distributed utility network **144** may allow number of utilities **146** to flow directly from number of utility sources **148** to one mobile system in plurality of mobile systems **134** over some number of utility cables. This one mobile system may then distribute number of utilities **146** to other mobile systems of plurality of mobile systems **134** such that these other mobile systems do not need to directly receive number of utilities **146** from number of utility sources **148.**

[0080] As depicted, distributed utility network **144** may be formed using utility system **138.** Utility system **138** may include utility fixture **150.** Utility system **138** may be configured to connect to number of utility sources **148** such that number of utilities **146** may flow from number of utility sources **148** to utility fixture **150.** Utility fixture **150** may be above-ground or in-ground, depending on the implementation. For example, without limitation, utility fixture **150** may be embedded in a floor within manufacturing environment **100.**

[0081] Utility fixture **150** may then distribute number of utilities **146** to one or more of plurality of mobile systems **134.** In particular, one autonomous coupling of one of plurality of mobile systems **134** to utility fixture **150** may be followed by any number of autonomous couplings of mobile systems to each other in series to form distributed utility network **144.** Utility fixture **150** may distribute number of utilities **146** to each of plurality of mobile systems **134** downstream of utility fixture **150** in the series of autonomous couplings of the mobile systems.

[0082] Depending on the implementation, distributed utility network **144** may have a chain-like configuration or a tree-like configuration. In one illustrative example, plurality of mobile systems **134** may include mobile systems A, B, C, and D (not shown in figure) with mobile system A autonomously coupled to utility fixture **150** and mobile systems B, C, and D autonomously coupled to mobile system A and each other in series. An example of a chain-like configuration for distributed utility network **144** may include number of utilities **146** flowing from number of utility sources **148** over some number of utility cables to utility fixture **150,** from utility fixture **150** to mobile system A, from mobile system A to mobile system B, from mobile system B to mobile system C, and from mobile system C to mobile system D. An example of a tree-like configuration for distributed utility network **144** may include number of utilities **146** flowing from number of utility sources **148** over some number of utility cables to utility fixture **150,** from utility fixture **150** to mobile system A, from mobile system A to both mobile system B and mobile system C, and from mobile system C to mobile system D. An example of one manner in which distributed utility network **144** may be implemented using plurality of mobile systems **134** is described in greater detail in **Figure 5** below.

[0083] In some illustrative examples, multiple flexible manufacturing systems may be used to build multiple fuselage assemblies concurrently. For example, flexible manufacturing system **106** may be a first flexible manufacturing system of many flexible manufacturing systems.

[0084] In one illustrative example, flexible manufacturing system **106,** second flexible manufacturing system **152,** and third flexible manufacturing system **154** may be used to build aft fuselage assembly **116,** middle fuselage assembly **118,** and forward fuselage assembly **117,** respectively.

[0085] Aft fuselage assembly **116,** middle fuselage assembly **118,** and forward fuselage assembly **117** may then be joined together to form a fully assembled fuselage **102.** In this manner, in this example, flexible manufacturing system **106,** second flexible manufacturing system **152,** and third flexible manufacturing system **154** may together form flexible fuselage manufacturing system **158.**

[0086] Thus, any number of fuselage assemblies, such as fuselage assembly **114,** may be built within manufacturing environment **100** using any number of flexible manufacturing systems implemented in a manner similar to flexible manufacturing system **106.** Similarly, any number of full fuselages, such as fuselage **102,** may be built within manufacturing environment **100** using any number of flexible fuselage manufacturing systems implemented in a manner similar to flexible fuselage manufacturing system **158.**

[0087] With reference now to **Figure 2,** an illustration of fuselage assembly **114** from **Figure 1** is depicted in the form of a block diagram in accordance with an illustrative embodiment. As described above, fuselage assembly **114** may include plurality of panels **120** and support structure **121.** Fuselage assembly **114** may be used to refer to any stage in the building of fuselage assembly **114.** For example, fuselage assembly **114** may be used to refer to a single one of plurality of panels **120,** multiple ones of plurality of panels **120** that have been or are being joined together, a partially built fuselage assembly, or a fully built fuselage assembly.

[0088] As depicted, fuselage assembly **114** may be built such that fuselage assembly **114** has plurality of fuselage sections **205.** Each of plurality of fuselage sections **205** may include one or more of plurality of panels **120.** In this illustrative example, each of plurality of fuselage sections **205** may take the form of a cylindrically-shaped fuselage section, a barrel-shaped fuselage section, a tapered cylindrical fuselage section, a cone-shaped fuselage section, a dome-shaped fuselage section, or a section having some other type of shape. Depending on the implementation, a fuselage section of plurality of fuselage sections **205** may have a shape that has a substantially circular cross-sectional shape, elliptical cross-sectional shape, oval cross-sectional shape, polygon with rounded corners cross-sectional shape, or otherwise closed-curve cross-sectional shape.

[0089] As one specific illustrative example, each of plurality of fuselage sections **205** may be a portion of fuselage assembly **114** defined between two radial crosssections of fuselage assembly **114** that are taken substantially perpendicular to a center axis or longitudinal axis through fuselage assembly **114.** In this manner, plurality of fuselage sections **205** may be arranged along the longitudinal axis of fuselage assembly **114.** In other words, plurality of fuselage sections **205** may be arranged longitudinally.

[0090] Fuselage section **207** may be an example of one of plurality of fuselage sections **205.** Fuselage section **207** may be comprised of one or more of plurality of panels **120.** In one illustrative example, multiple panel sections may be arranged circumferentially around fuselage section **207** to form the skin of fuselage section **207.** In some cases, multiple rows of two or more longitudinally adjacent panels may be arranged circumferentially around fuselage section **207** to form the skin of fuselage section **207.**

[0091] In one illustrative example, fuselage assembly **114** may have crown **200,** keel **202,** and sides **204.** Sides **204** may include first side **206** and second side **208.**

[0092] Crown **200** may be the top portion of fuselage assembly **114.** Keel **202** may be the bottom portion of fuselage assembly **114.** Sides **204** of fuselage assembly **114** may be the portions of fuselage assembly **114** between crown **200** and keel **202.** In one illustrative example, each of crown **200,** keel **202,** first side **206,** and second side **208** of fuselage assembly **114** may be formed by at least a portion of at least one of plurality of panels **120.** Further, a portion of each of plurality of fuselage sections **205** may form each of crown **200,** keel **202,** first side **206,** and second side **208.**

[0093] Panel **216** may be an example of one of plurality of panels **120.** Panel **216** may also be referred to as a skin panel, a fuselage panel, or a fuselage skin panel, depending on the implementation. In some illustrative examples, panel **216** may take the form of a mega-panel comprised of multiple smaller panels, which may be referred to as sub-panels. A mega-panel may also be referred to as a super panel. In these illustrative examples, panel **216** may be comprised of at least one of a metal, a metal alloy, some other type of metallic material, a composite material, or some other type of material. As one illustrative example, panel **216** may be comprised of an aluminum alloy, steel, titanium, a ceramic material, a composite material, some other type of material, or some combination thereof.

[0094] When used to form keel **202** of fuselage assembly **114,** panel **216** may be referred to as a keel panel or a bottom panel. When used to form one of sides **204** of fuselage assembly **114,** panel **216** may be referred to as a side panel. When used to form crown **200** of fuselage assembly **114,** panel **216** may be referred to as a crown panel or a top panel. As one illustrative example, plurality of panels **120** may include crown panels **218** for forming crown **200,** side panels **220** for forming sides **204,** and keel panels **222** for forming keel **202.** Side panels **220** may include first side panels **224** for forming first side **206** and second side panels **226** for forming second side **208.**

[0095] In one illustrative example, fuselage section **207** of plurality of fuselage sections **205** of fuselage assembly **114** may include one of crown panels **218,** two of side panels **220,** and one of keel panels **222.** In another illustrative example, fuselage section **207** may form an end of fuselage assembly **114.**

[0096] In some cases, fuselage section **207** may be comprised solely of a single panel, such as panel **216.** For example, without limitation, panel **216** may take the form of end panel **228.**

[0097] End panel **228** may be used to form one end of fuselage assembly **114.** For example, when fuselage assembly **114** takes the form of aft fuselage assembly **116** in **Figure 1,** end panel **228** may form the aftmost end of fuselage assembly **114.** When fuselage assembly **114** takes the form of forward fuselage assembly **117** in **Figure 1,** end panel **228** may form the forwardmost end of fuselage assembly **114.**

[0098] In one illustrative example, end panel **228** may take the form of a cylindrically-shaped panel, a cone-shaped panel, a barrel-shaped panel, or a tapered cylindrical panel. For example, end panel **228** may be a single cylindrically-shaped panel having a substantially circular cross-sectional shape that may change in diameter with respect to a center axis for fuselage assembly **114.**

[0099] In this manner, as described above, fuselage section **207** may be comprised solely of end panel **228.** In some illustrative examples, fuselage section **207** may be an end fuselage section that is comprised of only a single panel, which may be end panel **228.** In some cases, bulkhead **272** may be associated with end panel **228** when fuselage section **207** is an end fuselage section. Bulkhead **272,** which may also be referred to as a pressure bulkhead, may be considered separate from or part of end panel **228,** depending on the implementation. Bulkhead **272** may have a dome-type shape in these illustrative examples.

[0100] When fuselage assembly **114** takes the form of aft fuselage assembly **116** in **Figure 1,** bulkhead **272** may be part of fuselage section **207** located at the aftmost end of aft fuselage assembly **116.** When fuselage assembly **114** takes the form of forward fuselage assembly **117** in **Figure 1,** bulkhead **272** may be part of fuselage section **207** located at forwardmost end of aft fuselage assembly **116.** Middle fuselage assembly **118** in **Figure 1** may not include a bulkhead, such as bulkhead **272,** at either end of middle fuselage assembly **118.** In this manner, plurality of fuselage sections **205** may be implemented in any number of different ways.

[0101] Panel **216** may have first surface **230** and second surface **232.** First surface **230** may be configured for use as an exterior-facing surface. In other words, first surface **230** may be used to form exterior **234** of fuselage assembly **114.** Second surface **232** may be configured for use as an interior-facing surface. In other words, second surface **232** may be used to form interior **236** of fuselage assembly **114.** Each of plurality of panels **120** may be implemented in a manner similar to panel **216.**

[0102] As described earlier, support structure **121** may be associated with a corresponding one of plurality of panels **120.** Support structure **121** may be comprised of plurality of members **122** that are associated with panel **216.** In one illustrative example, corresponding portion **240** may be the portion of plurality of members **122** that correspond to panel **216.** Corresponding portion **240** may form support section **238** corresponding to panel **216.** Support section **238** may form a part of support structure **121.**

[0103] Plurality of members **122** may include support members **242.** Support members **242** may include, for example, without limitation, at least one of connecting members **244,** frames **246,** stringers **248,** stiffeners **250,** stanchions **252,** intercostal structural members **254,** or other types of structural members.

[0104] Connecting members **244** may connect other types of support members **242** together. In some cases, connecting members **244** may also connect support members **242** to plurality of panels **120.** Connecting members **244** may include, for example, without limitation, shear clips **256,** ties **258,** splices **260,** intercostal connecting members **262,** other types of mechanical connecting members, or some combination thereof.

[0105] In one illustrative example, when panel **216** is comprised of multiple sub-panels, connecting members **244** may be used to, for example, without limitation, connect together complementary frames of frames **246** running in the hoop-wise direction on adjacent sub-panels and complementary stringers of stringers **248** running in the longitudinal direction on adjacent sub-panels. In other illustrative examples, connecting members **244** may be used to connect together complementary frames, stringers, or other types of support members on two or more adjacent panels in plurality of panels **120.** In some cases, connecting members **244** may be used to connect together complementary support members on two or more adjacent fuselage sections.

[0106] Operations **124,** as described in **Figure 1,** may be performed to join plurality of panels **120** together to build fuselage assembly **114.** In one illustrative example, plurality of fasteners **264** may be used to join plurality of panels **120** together.

[0107] As described above, joining plurality of panels **120** together may be performed in a number of different ways. Joining plurality of panels **120** together may include at least one of joining at least one panel in plurality of panels **120** to another one of plurality of panels **120,** joining at least one panel in plurality of panels **120** to at least one of plurality of members **122,** joining at least one member in plurality of members **122** to another one of plurality of members **122,** or some other type of joining operation. Plurality of panels **120** may be joined together such that plurality of members **122** ultimately form support structure **121** for fuselage assembly **114.**

[0108] As depicted, number of floors **266** may be associated with fuselage assembly **114.** In this illustrative example, number of floors **266** may be part of fuselage assembly **114.** Number of floors **266** may include, for example, without limitation, at least one of a passenger floor, a cargo floor, or some other type of floor.

[0109] With reference now to **Figure 3,** an illustration of plurality of mobile systems **134** of flexible manufacturing system **106** within manufacturing environment **100** from **Figure 1** is depicted in the form of a block diagram in accordance with an illustrative embodiment. As depicted, flexible manufacturing system **106** may be used to build fuselage assembly **114** on floor **300** of manufacturing environment **100.** When manufacturing environment **100** takes the form of a factory, floor **300** may be referred to as factory floor **302.**

[0110] In one illustrative example, floor **300** may be substantially smooth and substantially planar. For example, floor **300** may be substantially level. In other illustrative examples, one or more portions of floor **300** may be sloped, ramped, or otherwise uneven.

[0111] Assembly area **304** may be an area within manufacturing environment **100** designated for performing assembly process **110** in **Figure 1** to build a fuselage assembly, such as fuselage assembly **114.** Assembly area **304** may also be referred to as a cell or a work cell. In this illustrative example, assembly area **304** may be a designated area on floor **300.** However, in other illustrative examples, assembly area **304** may include a designated area on floor **300** as well as the area above this designated area. Any number of assembly areas may be present within manufacturing environment **100** such that any number of fuselage assemblies may be built concurrently within manufacturing environment **100.**

[0112] As depicted, plurality of mobile systems **134** may include plurality of autonomous vehicles **306,** cradle system **308,** tower system **310,** and autonomous tooling system **312.** Each of plurality of mobile systems **134** may be drivable across floor **300.** In other words, each of plurality of mobile systems **134** may be capable of being autonomously driven across floor **300** from one location **315** to another location **317** on floor **300.**

[0113] In one illustrative example, each of plurality of autonomous vehicles **306** may take the form of an automated guided vehicle (AGV), which may be capable of operating independently without human direction or guidance. In some cases, plurality of autonomous vehicles **306** may be referred to as a plurality of automated guided vehicles (AGVs) .

[0114] In this illustrative example, cradle system **308** may be used to support and hold fuselage assembly **114** during assembly process **110** in **Figure 1.** In some cases, cradle system **308** may be referred to as a drivable cradle system. In still other cases, cradle system **308** may be referred to as an autonomously drivable cradle system.

[0115] Cradle system **308** may include number of fixtures **313.** As used herein, a "number of" items may include one or more items. In this manner, number of fixtures **313** may include one or more fixtures. In some illustrative examples, number of fixtures **313** may be referred to as a number of drivable fixtures. In other illustrative examples, number of fixtures **313** may be referred to as a number of autonomously drivable fixtures.

[0116] Number of fixtures **313** may include number of cradle fixtures **314.** In some illustrative examples, number of cradle fixtures **314** may be referred to as a number of drivable cradle fixtures. In other illustrative examples, number of cradle fixtures **314** may be referred to as a number of autonomously drivable cradle fixtures. Cradle fixture **322** may be an example of one of number of cradle fixtures **314.**

[0117] Number of retaining structures **326** may be associated with each of number of cradle fixtures **314.** Number of retaining structures **326** associated with each of number of cradle fixtures **314** may be engaged with and used to support fuselage assembly **114.** For example, number of retaining structures **326** associated with cradle fixture **322** may be engaged with and used to support one or more of plurality of panels **120.**

[0118] Number of cradle fixtures **314** may be autonomously driven across floor **300** of manufacturing environment **100** to assembly area **304.** In one illustrative example, each of number of cradle fixtures **314** may be autonomously driven across floor **300** using a corresponding one of plurality of autonomous vehicles **306.** In other words, without limitation, number of corresponding autonomous vehicles **316** in plurality of autonomous vehicles **306** may be used to drive number of cradle fixtures **314** across floor **300** into assembly area **304.**

[0119] In this illustrative example, number of corresponding autonomous vehicles **316** may drive from, for example, without limitation, holding area **318,** across floor **300,** to assembly area **304.** Holding area **318** may be an area in which at least one of plurality of autonomous vehicles **306,** cradle system **308,** tower system **310,** autonomous tooling system **312,** or control system **136** from **Figure 1** may be held when flexible manufacturing system **106** is not in use or when that particular device or system is not in use.

[0120] Holding area **318** may be referred to as a home area, a storage area, or a base area, depending on the implementation. Although holding area **318** is depicted as being located within manufacturing environment **100,** holding area **318** may be located in some other area or environment outside of manufacturing environment **100** in other illustrative examples.

[0121] Number of corresponding autonomous vehicles **316** in plurality of autonomous vehicles **306** may drive number of cradle fixtures **314** into number of selected cradle positions **320.** As used herein, a "position" may be comprised of a location, an orientation, or both. The location may be in two-dimensional coordinates or three-dimensional coordinates with respect to a reference coordinate system. The orientation may be a two-dimensional or three-dimensional orientation with respect to a reference coordinate system. This reference coordinate system may be, for example, without limitation, a fuselage coordinate system, an aircraft coordinate system, a coordinate system for manufacturing environment **100,** or some other type of coordinate system.

[0122] When number of cradle fixtures **314** includes more than one cradle fixture such that number of selected cradle positions **320** includes more than one cradle position, these cradle positions may be positions selected relative to each other. In this manner, number of cradle fixtures **314** may be positioned such that number of cradle fixtures **314** are in number of selected cradle positions **320** relative to each other.

[0123] In these illustrative examples, number of corresponding autonomous vehicles **316** may be used to drive number of cradle fixtures **314** into number of selected cradle positions **320** within assembly area **304.** "Driving" a component or a system across floor **300** may mean, for example, but not limited to, moving substantially the entirety of that component or system from one location to another location. For example, without limitation, driving cradle fixture **322** across floor **300** may mean moving the entirety of cradle fixture **322** from one location to another location. In other words, all or substantially all components that comprise cradle fixture **322** may be simultaneously moved together from one location to another location.

[0124] Once number of cradle fixtures **314** has been driven into number of selected cradle positions **320** in assembly area **304,** number of cradle fixtures **314** may be coupled to each other and to tower system **310.** Number of corresponding autonomous vehicles **316** may then drive away from number of cradle fixtures **314** to, for example, without limitation, holding area **318,** once number of cradle fixtures **314** is positioned in number of selected cradle positions **320** within selected tolerances. In other illustrative examples, number of corresponding autonomous vehicles **316** may be comprised of a single autonomous vehicle that is used to drive each of number of cradle fixtures **314** into a corresponding selected position in number of selected cradle positions **320** within assembly area **304** one at a time.

[0125] In assembly area **304,** number of cradle fixtures **314** may be configured to form assembly fixture **324.** Assembly fixture **324** may be formed when the different cradle fixtures in number of cradle fixtures **314** have been placed in number of selected cradle positions **320** relative to each other. In some cases, assembly fixture **324** may be formed when number of cradle fixtures **314** have been coupled to each other while number of cradle fixtures **314** is in number of selected cradle positions **320** and when number of retaining structures **326** associated with each of number of cradle fixtures **314** has been adjusted to receive fuselage assembly **114.**

[0126] In this manner, number of cradle fixtures **314** may form a single fixture entity, such as assembly fixture **324.** Assembly fixture **324** may be used to support and hold fuselage assembly **114.** In some cases, assembly fixture **324** may be referred to as an assembly fixture system or a fixture system. In some cases, assembly fixture **324** may be referred to as a drivable assembly fixture. In other cases, assembly fixture **324** may be referred to as an autonomously drivable assembly fixture.

[0127] Once assembly fixture **324** has been formed, number of cradle fixtures **314** may receive fuselage assembly **114.** In other words, plurality of fuselage sections **205** may be engaged with number of cradle fixtures **314.** In particular, plurality of fuselage sections **205** may be engaged with number of retaining structures **326** associated with each of number of cradle fixtures **314.** Plurality of fuselage sections **205** may be engaged with number of cradle fixtures **314** in any number of ways.

[0128] When number of cradle fixtures **314** includes a single cradle fixture, that cradle fixture may be used to support and hold substantially the entire fuselage assembly **114.** When number of cradle fixtures **314** includes multiple cradle fixtures, each of these cradle fixtures may be used to support and hold at least one corresponding fuselage section of plurality of fuselage sections **205.**

[0129] In one illustrative example, each of plurality of fuselage sections **205** may be engaged with number of cradle fixtures **314** one at a time. For example, without limitation, all of the panels for a particular fuselage section in plurality of fuselage sections **205** may be positioned relative to each other and a corresponding cradle fixture in number of cradle fixtures **314** and then engaged with the corresponding cradle fixture. The remaining fuselage sections in plurality of fuselage sections **205** may then be formed and engaged with number of cradle fixtures **314** in a similar manner. In this manner, plurality of panels **120** may be engaged with number of cradle fixtures **314** by engaging at least a portion of plurality of panels **120** with number of retaining structures **326** associated with each of number of cradle fixtures **314** that makes up assembly fixture **324** such that plurality of panels **120** is supported by number of cradle fixtures **314.**

[0130] As described in **Figure 2,** plurality of panels **120** may include keel panels **222,** side panels **220,** and crown panels **218.** In one illustrative example, all of keel panels **222** in **Figure 2** used to form keel **202** of fuselage assembly **114** in **Figure 2** may first be positioned relative to and engaged with number of cradle fixtures **314.** Next, all of side panels **220** in **Figure 2** used to form sides **204** of fuselage assembly **114** in **Figure 2** may be positioned relative to and engaged with keel panels **222.** Then, all of crown panels **218** in **Figure 2** used to form crown **200** of fuselage assembly **114** in **Figure 2** may be positioned relative to and engaged with side panels **220.** In this manner, plurality of fuselage sections **205** may be concurrently assembled to form fuselage assembly **114.**

[0131] In one illustrative example, each panel in plurality of panels **120** may have a corresponding portion of plurality of members **122** fully formed and associated with the panel prior to the panel being engaged with one of number of cradle fixtures **314.** This corresponding portion of plurality of members **122** may be referred to as a support section. For example, support section **238** in **Figure 2** may be fully formed and associated with panel **216** in **Figure 2** prior to panel **216** being engaged with one of number of cradle fixtures **314** or another panel of plurality of panels **120** in **Figure 2.** In other words, a corresponding portion of support members **242** in **Figure 2** may already be attached to panel **216** and a corresponding portion of connecting members **244** in **Figure 2** already installed to connect this portion of support members **242** to each other prior to panel **216** from **Figure 2** being engaged with one of number of cradle fixtures **314.**

[0132] In other illustrative examples, plurality of members **122** may be associated with plurality of panels **120** after plurality of panels **120** have been engaged with each other and number of cradle fixtures **314.** In still other illustrative examples, only a portion of plurality of members **122** may be associated with plurality of panels **120** prior to plurality of panels **120** being engaged with each other and number of cradle fixtures **314** and then a remaining portion of plurality of members **122** associated with plurality of panels **120** once plurality of panels **120** have been engaged with each other and number of cradle fixtures **314.**

[0133] In some illustrative examples, one or more of support members **242** in **Figure 2,** one or more of connecting members **244** in **Figure 2,** or both may not be associated with panel **216** when panel **216** from **Figure 2** is engaged with one of number of cradle fixtures **314** or with one of the other panels in plurality of panels **120.** For example, without limitation, frames **246** described in **Figure 2** may be added to panel **216** from **Figure 2** after panel **216** has been engaged with cradle fixture **322.** In another example, stiffeners **250** described in **Figure 2** may be added to panel **216** from **Figure 2** after panel **216** has been engaged with cradle fixture **322.**

[0134] Building fuselage assembly **114** may include engaging plurality of panels **120** with each other as plurality of panels **120** are built up on number of cradle fixtures **314** of assembly fixture **324.** For example, adjacent panels in plurality of panels **120** may be connected by connecting at least a portion of the support members associated with the panels. Depending on the implementation, at least one of lap splices, butt splices, or other types of splices may be used to connect the adjacent panels in addition to or in place of connecting the corresponding support members of the adjacent panels.

[0135] As one illustrative example, the support members associated with two adjacent panels in plurality of panels **120** may be connected together using connecting members, thereby connecting the two adjacent panels. The two support members associated with these two adjacent panels may be, for example, without limitation, spliced, tied, clipped, tacked, pinned, joined, or fastened together in some other manner. When the two adjacent panels are hoop-wise adjacent, complementary frames may be connected in the hoop-wise direction. When the two adjacent panels are longitudinally adjacent, complementary stringers may be connected in the longitudinal direction.

[0136] In some cases, connecting complementary stringers, frames, or other support members on these two adjacent panels may be part of splicing these panels together. Adjacent panels may be connected together using any number of panel splices, stringer splices, frame splices, or other types of splices.

[0137] In one illustrative example, plurality of panels 120 may be temporarily connected to each other by temporarily fastening at least one of plurality of panels **120** or plurality of members **122** together using temporary fasteners or permanent fasteners. For example, without limitation, temporary clamps may be used to temporarily connect and hold in place two of plurality of panels **120** together. Temporarily connecting plurality of panels **120** together may be performed by at least one of temporarily connecting at least two plurality of panels **120** together, temporarily connecting at least two plurality of members **122** together, or temporarily connecting at least one of plurality of panels **120** to at least one of plurality of members **122** such that plurality of members **122** associated with plurality of panels **120** forms support structure **121** in **Figure 2** for fuselage assembly **114.**

[0138] As one illustrative example, plurality of panels **120** may be temporarily tacked or pinned together using temporary fasteners **328** until plurality of fasteners **264** are installed to join plurality of panels **120** together to form fuselage assembly **114.** Temporarily connecting plurality of panels **120** may temporarily connect together plurality of fuselage sections **205** from **Figure 2** formed by plurality of panels **120.** Once plurality of fasteners **264** have been installed, temporary fasteners **328** may then be removed.

[0139] In this manner, plurality of panels **120** may be connected together in a number of different ways. Once plurality of panels **120** have been connected together, plurality of members **122** may be considered as forming support structure **121** for fuselage assembly **114.** Connecting plurality of panels **120** together and forming support structure **121** may maintain desired compliance with outer mold line requirements and inner mold line requirements for fuselage assembly **114.** In other words, plurality of panels **120** may be held together in place relative to each other such that fuselage assembly **114** formed using plurality of panels **120** meets outer mold line requirements and inner mold line requirements for fuselage assembly **114** within selected tolerances.

[0140] In particular, assembly fixture **324** may support plurality of panels **120** and support structure **121** associated with plurality of panels **120** such that fuselage assembly **114** built using plurality of panels **120** and support structure **121** has a shape and a configuration that is within selected tolerances. In this manner, this shape and configuration may be maintained within selected tolerances while supporting plurality of panels **120** and plurality of members **122** associated with plurality of panels **120** during the building of fuselage assembly **114.** This shape may be at least partially determined by, for example, without limitation, the outer mold line requirements and inner mold line requirements for fuselage assembly **114.** In some cases, the shape may be at least partially determined by the location and orientation of the frames and stringers of fuselage assembly **114.**

[0141] In some cases, when the assembly of plurality of panels **120** and support structure **121** that comprise fuselage assembly **114** has reached a desired point, number of corresponding autonomous vehicles **316** may drive assembly fixture **324** out of assembly area **304.** For example, fuselage assembly **114** may be driven across floor **300** into a different area within manufacturing environment **100,** from floor **300** onto another floor in a different manufacturing environment, or from floor **300** onto another floor in some other area or environment.

[0142] In one illustrative example, assembly fixture **324** may be driven to some other location at which another assembly fixture is located such that the two assembly fixtures may be coupled to form a larger assembly fixture. As one illustrative example, assembly fixture **324** may be used to hold and support aft fuselage assembly **116** in **Figure 1,** while another assembly fixture implemented in a manner similar to assembly fixture **324** may be used to hold and support forward fuselage assembly **117** in **Figure 1.** Yet another assembly fixture implemented in a manner similar to assembly fixture **324** may be used to hold and support middle fuselage assembly **118** in **Figure 1.**

[0143] Once these three fuselage assemblies have been built, the three assembly fixtures may be brought together to form a larger assembly fixture for holding aft fuselage assembly **116,** middle fuselage assembly **118,** and forward fuselage assembly **117** such that these three fuselage assemblies may be joined to form fuselage **102** described in **Figure 1.** In particular, this larger assembly fixture may hold aft fuselage assembly **116,** middle fuselage assembly **118,** and forward fuselage assembly **117** in alignment with each other such that fuselage **102** may be built within selected tolerances.

[0144] In another illustrative example, a first assembly fixture and a second assembly fixture implemented in a manner similar to assembly fixture **324** may be used to hold and support aft fuselage assembly **116** and forward fuselage assembly **117,** respectively, from **Figure 1.** Once these two fuselage assemblies have been built, the two assembly fixtures may then be brought together to form a larger assembly fixture for holding the two fuselage assemblies such that these fuselage assemblies may be joined to form fuselage **102.** The larger assembly fixture may hold aft fuselage assembly **116** and forward fuselage assembly **117** in alignment with each other such that fuselage **102** may be built within selected tolerances.

[0145] As depicted, tower system **310** includes number of towers **330.** Tower **332** may be an example of one implementation for one of number of towers **330.** Tower **332** may be configured to provide access to interior **236** of fuselage assembly **114** described in **Figure 2.** In some illustrative examples, tower **332** may be referred to as a drivable tower. In other illustrative examples, tower **332** may be referred to as an autonomously drivable tower.

[0146] In one illustrative example, tower **332** may take the form of first tower **334.** First tower **334** may also be referred to as an operator tower in some cases. In another illustrative example, tower **332** may take the form of second tower **336.** Second tower **336** may also be referred to as a robotics tower in some cases. In this manner, number of towers **330** may include both first tower **334** and second tower **336.**

[0147] First tower **334** may be configured substantially for use by a human operator, whereas second tower **336** may be configured substantially for use by a mobile platform having at least one robotic device associated with the mobile platform. In other words, first tower **334** may allow a human operator to access and enter interior **236** of fuselage assembly **114.** Second tower **336** may allow a mobile platform to access and enter interior **236** of fuselage assembly **114.**

[0148] First tower **334** and second tower **336** may be positioned relative to assembly fixture **324** at different times during assembly process **110.** As one illustrative example, one of plurality of autonomous vehicles **306** may be used to move or autonomously drive first tower **334** from holding area **318** into selected tower position **338** within assembly area **304.** Number of cradle fixtures **314** may then be autonomously driven, using number of corresponding autonomous vehicles **316,** into number of selected cradle positions **320** relative to first tower **334,**

which is in selected tower position **338** within assembly area **304.**

[0149] Second tower **336** may be exchanged for first tower **334** at some later stage during assembly process **110** in **Figure 1.** For example, one of plurality of autonomous vehicles **306** may be used to autonomously drive first tower **334** out of assembly area **304** and back into holding area **318.** The same autonomous vehicle or a different autonomous vehicle in plurality of autonomous vehicles **306** may then be used to autonomously drive second tower **336** from holding area **318** into selected tower position **338** within assembly area **304** that was previously occupied by first tower **334.** Depending on the implementation, first tower **334** may be later exchanged for second tower **336.**

[0150] In other illustrative examples, first tower **334** and second tower **336** may each have an autonomous vehicle in plurality of autonomous vehicles **306** fixedly associated with the tower. In other words, one of plurality of autonomous vehicles **306** may be integrated with first tower **334** and one of plurality of autonomous vehicles **306** may be integrated with second tower **336.** For example, one of plurality of autonomous vehicles **306** may be considered part of or built into first tower **334.** First tower **334** may then be considered capable of autonomously driving across floor **300.** In a similar manner, one of plurality of autonomous vehicles **306** may be considered part of or built into second tower **336.** Second tower **336** may then be considered capable of autonomously driving across floor **300.**

[0151] Tower system **310** and assembly fixture **324** may be configured to form interface **340** with each other. Interface **340** may be a physical interface between tower system **310** and assembly fixture **324.** Tower system **310** may also be configured to form interface **342** with utility system **138.** In one illustrative example, interface **340** and interface **342** may be autonomously formed.

[0152] Interface **342** may be a physical interface between tower system **310** and utility system **138.** In these illustrative examples, in addition to being physical interfaces, interface **340** and interface **342** may also be utility interfaces. For example, with respect to the utility of power, interface **340** and interface **342** may be considered electrical interfaces.

[0153] Utility system **138** is configured to distribute number of utilities **146** to tower system **310** when tower system **310** and utility system **138** are physically and electrically coupled through interface **342.** Tower system **310** may then distribute number of utilities **146** to assembly fixture **324** formed by cradle system **308** when assembly fixture **324** and tower system **310** are physically and electrically coupled through interface **340.** Number of utilities **146** may include at least one of power, air, hydraulic fluid, communications, water, or some other type of utility.

[0154] As depicted, utility system **138** may include utility fixture **150.** Utility fixture **150** may be configured to receive number of utilities **146** from number of utility sources **148.** Number of utility sources **148** may include, for example, without limitation, at least one of a power generator, a battery system, a water system, an electrical line, a communications system, a hydraulic fluid system, an air tank, or some other type of utility source. For example, utility fixture **150** may receive power from a power generator.

[0155] In one illustrative example, utility fixture **150** may be positioned relative to assembly area **304.** Depending on the implementation, utility fixture **150** may be positioned inside assembly area **304** or outside of assembly area **304.**

[0156] In some illustrative examples, utility fixture **150** may be associated with floor **300.** Depending on the implementation, utility fixture **150** may be permanently associated with floor **300** or temporarily associated with floor **300.** In other illustrative examples, utility fixture **150** may be associated with some other surface of manufacturing environment **100,** such as a ceiling, or some other structure in manufacturing environment **100.** In some cases, utility fixture **150** may be embedded within floor **300.**

[0157] In one illustrative example, first tower **334** may be autonomously driven into selected tower position **338** with respect to floor **300** relative to utility fixture **150** such that interface **342** may be formed between first tower **334** and utility fixture **150.** Once interface **342** has been formed, number of utilities **146** may flow from utility fixture **150** to first tower **334.** Assembly fixture **324** may then autonomously form interface **340** with first tower **334** to form a network of utility cables between first tower **334** and assembly fixture **324.** Once both interface **342** and interface **340** have been formed, number of utilities **146** received at utility fixture **150** may flow from utility fixture **150** to first tower **334** and to each of number of cradle fixtures **314** that forms assembly fixture **324.** In this manner, first tower **334** may function as a conduit or "middleman" for distributing number of utilities **146** to assembly fixture **324.**

[0158] When interface **340** has been formed between second tower **336** and assembly fixture **324** and interface **342** has been formed between second tower **336** and utility fixture **150,** number of utilities **146** may be provided to second tower **336** and assembly fixture **324** in a similar manner as described above. Thus, utility fixture **150** may distribute number of utilities **146** to tower system **310** and assembly fixture **324** without tower system **310** and cradle assembly fixture **324** having to separately connect to number of utility sources **148** or any other utility sources.

[0159] Autonomous tooling system **312** may be used to assemble plurality of panels **120** and support structure **121** while fuselage assembly **114** is being supported and held by assembly fixture **324.** Autonomous tooling system **312** may include plurality of mobile platforms **344.** Each of plurality of mobile platforms **344** may be configured to perform one or more of operations **124** in assembly process **110** described in **Figure 1.** In particular, plurality of mobile platforms **344** may be autonomously driven into selected positions relative to plurality of panels **120** within selected tolerances to autonomously perform operations **124** that join plurality of panels **120** together to build fuselage assembly **114.** Plurality of mobile platforms **344** are described in greater detail in **Figure 4** below.

[0160] In this illustrative example, set of controllers **140** in control system **136** may generate commands **142** as described in **Figure 1** to control the operation of at least one of cradle system **308,** tower system **310,** utility system **138,** autonomous tooling system **312,** or plurality of autonomous vehicles **306.** Set of controllers **140** in **Figure 1** may communicate with at least one of cradle system **308,** tower system **310,** utility system **138,** autonomous tooling system **312,** or plurality of autonomous vehicles **306** using any number of wireless communications links, wired communications links, optical communications links, other types of communications links, or combination thereof.

[0161] In this manner, plurality of mobile systems **134** of flexible manufacturing system **106** may be used to automate the process of building fuselage assembly **114.** Plurality of mobile systems **134** may enable fuselage assembly **114** to be built substantially autonomously with respect to joining together plurality of panels **120** to reduce the overall time, effort, and human resources needed.

[0162] Flexible manufacturing system **106** may build fuselage assembly **114** up to the point needed to move fuselage assembly **114** to the next stage in manufacturing process **108** for building fuselage **102** or the next stage in the manufacturing process for building aircraft **104,** depending on the implementation. In some cases, cradle system **308** in the form of assembly fixture **324** may continue carrying and supporting fuselage assembly **114** during one or more of these later stages in manufacturing process **108** for building fuselage **102** and aircraft **104.**

[0163] With reference now to **Figure 4,** an illustration of plurality of mobile platforms **344** from **Figure 3** is depicted in the form of a block diagram in accordance with an illustrative embodiment. As depicted, plurality of mobile platforms **344** may include number of external mobile platforms **400** and number of internal mobile platforms **402.** In this manner, plurality of mobile platforms **344** may include at least one external mobile platform and at least one internal mobile platform.

[0164] In some illustrative examples, number of external mobile platforms **400** may be referred to as a number of drivable external mobile platforms. Similarly, in some cases, number of internal mobile platforms **402** may be referred to as a number of drivable internal mobile platforms. In other illustrative examples, number of external mobile platforms **400** and number of internal mobile platforms **402** may be referred to as a number of autonomously drivable external mobile platforms and a number of autonomously drivable internal mobile platforms, respectively.

[0165] External mobile platform **404** may be an example of one of number of external mobile platforms **400** and internal mobile platform **406** may be an example of one of number of internal mobile platforms **402.** External mobile platform **404** and internal mobile platform **406** may be platforms that are autonomously drivable. Depending on the implementation, each of external mobile platform **404** and internal mobile platform **406** may be configured to autonomously drive across floor **300** on its own or with the assistance of one of plurality of autonomous vehicles **306** from **Figure 3.**

[0166] As one illustrative example, without limitation, external mobile platform **404** may be autonomously driven across floor **300** using a corresponding one of plurality of autonomous vehicles **306.** In some illustrative examples, external mobile platform **404** and this corresponding one of plurality of autonomous vehicles **306** may be integrated with each other. For example, the autonomous vehicle may be fixedly associated with external mobile platform **404.** An entire load of external mobile platform **404** may be transferable to the autonomous vehicle such that driving the autonomous vehicle across floor **300** drives external mobile platform **404** across floor **300.**

[0167] External mobile platform **404** may be driven from, for example, without limitation, holding area **318** to a position relative to exterior **234** of fuselage assembly **114** to perform one or more operations **124** in **Figure 1.** As depicted, at least one external robotic device **408** may be associated with external mobile platform **404.** In this illustrative example, external robotic device **408** may be considered part of external mobile platform **404.** In other illustrative examples, external robotic device **408** may be considered a separate component that is physically attached to external mobile platform **404.** External robotic device **408** may take the form of, for example, without limitation, a robotic arm.

[0168] External robotic device **408** may have first end effector **410.** Any number of tools may be associated with first end effector **410.** These tools may include, for example, without limitation, at least one of a drilling tool, a fastener insertion tool, a fastener installation tool, an inspection tool, or some other type of tool. In particular, any number of fastening tools may be associated with first end effector **410.**

[0169] As depicted, first tool **411** may be associated with first end effector **410.** In one illustrative example, first tool **411** may be any tool that is removably associated with first end effector **410.** In other words, first tool **411** associated with first end effector **410** may be changed as various operations need to be performed. For example, without limitation, first tool **411** may take the form of one type of tool, such as a drilling tool, to perform one type of operation. This tool may then be exchanged with another type of tool, such as a fastener insertion tool, to become the new first tool **411** associated with first end effector **410** to perform a different type of operation.

[0170] In one illustrative example, first tool **411** may take the form of first riveting tool **412.** First riveting tool

412 may be used to perform riveting operations. In some illustrative examples, a number of different tools may be exchanged with first riveting tool **412** and associated with first end effector **410.** For example, without limitation, first riveting tool **412** may be exchangeable with a drilling tool, a fastener insertion tool, a fastener installation tool, an inspection tool, or some other type of tool.

[0171] External mobile platform **404** may be autonomously driven across floor **300** and positioned relative to assembly fixture **324** in **Figure 3** supporting fuselage assembly **114** to position first end effector **410** and first tool **411** associated with first end effector **410** relative to one of plurality of panels **120.** For example, external mobile platform **404** may be autonomously driven across floor **300** to external position **414** relative to assembly fixture **324.** In this manner, first tool **411** carried by external mobile platform **404** may be macro-positioned using external mobile platform **404.**

[0172] Once in external position **414,** first end effector **410** may be autonomously controlled using at least external robotic device **408** to position first tool **411** associated with first end effector **410** relative to a particular location on an exterior-facing side of one of plurality of panels **120.** In this manner, first tool **411** may be micro-positioned relative to the particular location.

[0173] Internal mobile platform **406** may be located on second tower **336** in **Figure 3** when internal mobile platform **406** is not in use. When interface **342** described in **Figure 3** is formed between second tower **336** and assembly fixture **324,** internal mobile platform **406** may be driven from second tower **336** into interior **236** of fuselage assembly **114** and used to perform one or more of operations **124.** In one illustrative example, internal mobile platform **406** may have a movement system that allows internal mobile platform **406** to move from second tower **336** onto a floor inside fuselage assembly **114.**

[0174] At least one internal robotic device **416** may be associated with internal mobile platform **406.** In this illustrative example, internal robotic device **416** may be considered part of internal mobile platform **406.** In other illustrative examples, internal robotic device **416** may be considered a separate component that is physically attached to internal mobile platform **406.** Internal robotic device **416** may take the form of, for example, without limitation, a robotic arm.

[0175] Internal robotic device **416** may have second end effector **418.** Any number of tools may be associated with second end effector **418.** For example, without limitation, at least one of a drilling tool, a fastener insertion tool, a fastener installation tool, an inspection tool, or some other type of tool may be associated with second end effector **418.** In particular, any number of fastening tools may be associated with second end effector **418.**

[0176] As depicted, second tool **419** may be associated with second end effector **418.** In one illustrative example, second tool **419** may be any tool that is removably associated with second end effector **418.** In other words, second tool **419** associated with second end effector **418** may be changed as various operations need to be performed. For example, without limitation, first tool **411** may take the form of one type of tool, such as a drilling tool, to perform one type of operation. This tool may then be exchanged with another type of tool, such as a fastener insertion tool, to become the new first tool **411** associated with first end effector **410** to perform a different type of operation.

[0177] In one illustrative example, second tool **419** may take the form of second riveting tool **420.** Second riveting tool **420** may be associated with second end effector **418.** Second riveting tool **420** may be used to perform riveting operations. In some illustrative examples, a number of different tools may be exchanged with second riveting tool **420** and associated with second end effector **418.** For example, without limitation, second riveting tool **420** may be exchangeable with a drilling tool, a fastener insertion tool, a fastener installation tool, an inspection tool, or some other type of tool.

[0178] Internal mobile platform **406** may be driven from second tower **336** into fuselage assembly **114** and positioned relative to interior **236** of fuselage assembly **114** to position second end effector **418** and second tool **419** associated with second end effector **418** relative to one of plurality of panels **120.** In one illustrative example, internal mobile platform **406** may be autonomously driven onto one of number of floors **266** in **Figure 2** into internal position **422** within fuselage assembly **114** relative to fuselage assembly **114.** In this manner, second tool **419** may be macro-positioned into internal position **422** using internal mobile platform **406.**

[0179] Once in internal position **422,** second end effector **418** may be autonomously controlled to position second tool **419** associated with second end effector **418** relative to a particular location on an interior-facing side of one of plurality of panels **120** or an interior-facing side of one of plurality of members **122** in **Figure 2** that make up support structure **121.** In this manner, second tool **419** may be micro-positioned relative to the particular location.

[0180] In one illustrative example, external position **414** for external mobile platform **404** and internal position **422** for internal mobile platform **406** may be selected such that fastening process **424** may be performed at location **426** on fuselage assembly **114** using external mobile platform **404** and internal mobile platform **406.** Fastening process **424** may include any number of operations. In one illustrative example, fastening process **424** may include at least one of drilling operation **428,** fastener insertion operation **430,** fastener installation operation **432,** inspection operation **434,** or some other type of operation.

[0181] As one specific example, drilling operation **428** may be performed autonomously using first tool **411** associated with first end effector **410** of external mobile platform **404** or second tool **419** associated with second end effector **418** of internal mobile platform **406.** For example, without limitation, first tool **411** or second tool **419**

may take the form of a drilling tool for use in performing drilling operation **428.** Drilling operation **428** may be autonomously performed using first tool **411** or second tool **419** to form hole **436** at location **426.** Hole **436** may pass through at least one of two panels in plurality of panels **120,** two members of a plurality of members **122,** or a panel and one of plurality of members **122.**

[0182] Fastener insertion operation **430** may be performed autonomously using first tool **411** associated with first end effector **410** of external mobile platform **404** or second tool **419** associated with second end effector **418** of internal mobile platform **406.** Fastener insertion operation **430** may result in fastener **438** being inserted into hole **436.**

[0183] Fastener installation operation **432** may then be performed autonomously using at least one of first tool **411** associated with first end effector **410** of external mobile platform **404** or second tool **419** associated with second end effector **418** of internal mobile platform **406.** In one illustrative example, fastener installation operation **432** may be performed autonomously using first tool **411** in the form of first riveting tool **412** and second tool **419** in the form of second riveting tool **420** such that fastener **438** becomes rivet **442** installed at location **426.** Rivet **442** may be a fully installed rivet. Rivet **442** may be one of plurality of fasteners **264** described in **Figure 2.**

[0184] In one illustrative example, fastener installation operation **432** may take the form of bolt-nut type installation process **433.** First tool **411** associated with first end effector **410** may be used to, for example, without limitation, install bolt **435** through hole **436.** Second tool **419** associated with second end effector **418** may then be used to install nut **437** over bolt **435.** In some cases, installing nut **437** may include applying a torque sufficient to nut **437** such that a portion of nut **437** breaks off. In these cases, nut **437** may be referred to as a frangible collar.

[0185] In another illustrative example, fastener installation operation **432** may take the form of interference-fit bolt-type installation process **439.** First tool **411** associated with first end effector **410** may be used to, for example, without limitation, install bolt **435** through hole **436** such that an interference fit is created between bolt **435** and hole **436.** Second tool **419** associated with second end effector **418** may then be used to install nut **437** over bolt **435.**

[0186] In yet another illustrative example, fastener installation operation **432** may take the form of two-stage riveting process **444.** Two-stage riveting process **444** may be performed using, for example, without limitation, first riveting tool **412** associated with external mobile platform **404** and second riveting tool **420** associated with internal mobile platform **406.**

[0187] For example, first riveting tool **412** and second riveting tool **420** may be positioned relative to each other by external mobile platform **404** and internal mobile platform **406,** respectively. For example, external mobile platform **404** and external robotic device **408** may be used to position first riveting tool **412** relative to location **426** at exterior **234** of fuselage assembly **114.** Internal mobile platform **406** and internal robotic device **416** may be used to position second riveting tool **420** relative to the same location **426** at interior **236** of fuselage assembly **114.**

[0188] First riveting tool **412** and second riveting tool **420** may then be used to perform two-stage riveting process **444** to form rivet **442** at location **426.** Rivet **442** may join at least two of plurality of panels **120** together, a panel in plurality of panels **120** to support structure **121** formed by plurality of members **122,** or two panels in plurality of panels **120** to support structure **121.**

[0189] In this example, two-stage riveting process **444** may be performed at each of plurality of locations **446** on fuselage assembly **114** to install plurality of fasteners **264** as described in **Figure 2.** Two-stage riveting process **444** may ensure that plurality of fasteners **264** in **Figure 2** are installed at plurality of locations **446** with a desired quality and desired level of accuracy.

[0190] In this manner, internal mobile platform **406** may be autonomously driven and operated inside fuselage assembly **114** to position internal mobile platform **406** and second riveting tool **420** associated with internal mobile platform **406** relative to plurality of locations **446** on fuselage assembly **114** for performing assembly process **110** described in **Figure 1.** Similarly, external mobile platform **404** may be autonomously driven and operated around fuselage assembly **114** to position external mobile platform **404** and first riveting tool **412** associated with external mobile platform **404** relative to plurality of locations **446** on fuselage assembly **114** for performing operations **124.**

[0191] With reference now to **Figure 5,** an illustration of a flow of number of utilities **146** across distributed utility network **144** from **Figure 1** is depicted in the form of a block diagram in accordance with an illustrative embodiment. As depicted, number of utilities **146** may be distributed across distributed utility network **144.**

[0192] Distributed utility network **144** may include, for example, without limitation, number of utility sources **148,** utility fixture **150,** number of towers **330,** assembly fixture **324,** number of external mobile platforms **400,** and number of utility units **500.** In some cases, distributed utility network **144** may also include number of internal mobile platforms **402.** In some illustrative examples, number of utility sources **148** may be considered separate from distributed utility network **144.**

[0193] In this illustrative example, only one of number of towers **330** may be included in distributed utility network **144** at a time. When first tower **334** is used, distributed utility network **144** may be formed when utility fixture **150** is coupled to number of utility sources **148,** first tower **334** is coupled to utility fixture **150,** assembly fixture **324** is coupled to first tower **334,** and number of external mobile platforms **400** is coupled to number of utility units **500.**

[0194] Number of utility units **500** may be associated with number of cradle fixtures **314** of assembly fixture

324 or separated from number of cradle fixtures **314.** For example, without limitation, a number of dual interfaces may be created between number of external mobile platforms **400,** number of utility units **500,** and number of cradle fixtures **314** using one or more dual-interface couplers.

[0195] When second tower **336** is used, distributed utility network **144** may be formed when utility fixture **150** is coupled to number of utility sources **148,** second tower **336** is coupled to utility fixture **150,** assembly fixture **324** is coupled to second tower **336,** number of internal mobile platforms **402** is coupled to second tower **336,** and number of external mobile platforms **400** is coupled to number of utility units **500,** which may be associated with number of cradle fixtures **314** or separated from number of cradle fixtures **314.** Number of internal mobile platforms **402** may receive number of utilities **146** through a number of cable management systems associated with second tower **336.**

[0196] In this manner, number of utilities **146** may be distributed across distributed utility network **144** using a single utility fixture **150.** This type of distributed utility network **144** may reduce the number of utility components, utility cables, and other types of devices needed to provide number of utilities **146** to the various components in distributed utility network **144.** Further, with this type of distributed utility network **144,** starting from at least utility fixture **150,** number of utilities **146** may be provided completely above floor **300** of manufacturing environment in **Figure 1.**

[0197] With reference now to **Figure 6,** an illustration of internal mobile platform **406** from **Figure 4** is depicted in the form of a block diagram in accordance with an illustrative embodiment. As depicted, internal mobile platform **406** may include platform base **600.** Number of robotic systems **602** may be associated with platform base **600.** In other words, one or more of number of robotic systems **602** may be associated with platform base **600.**

[0198] In this illustrative example, number of robotic systems **602** may include, for example, first robotic system **606** and second robotic system **608.** In this illustrative example, first robotic system **606** may include first robotic base **610** and first robotic device **612.** First robotic device **612** may be associated with first robotic base **610.** In some cases, first robotic device **612** may be movably associated with first robotic base **610.** For example, first robotic device **612** may be configured to at least one of rotate or translate relative to first robotic base **610.** In other illustrative examples, first robotic base **610** may be considered part of first robotic device **612.**

[0199] As depicted, first robotic system **606** may also include first movement system **614** and first robotic controller **616.** First movement system **614** may control the movement of at least one of first robotic device **612** relative to first robotic base **610** or first robotic base **610** relative to platform base **600.** First movement system **614** may include at least one of an actuator device, a motor, a rail system, a track system, a slide system, a roller, a wheel, omnidirectional wheels, a pulley system, an elbow movement system, a wrist movement system, a swivel system, or an X-Y table.

[0200] First robotic controller **616** may control the operation of first movement system **614.** For example, first movement system **614** may be comprised of one or more movement devices that may be computer numerically-controlled. First robotic controller **616** may include, for example, without limitation, any number of control devices, computers, integrated circuits, microprocessors, other types of processing units, or combination thereof.

[0201] In this illustrative example, second robotic system **608** may include second robotic base **618** and second robotic device **620.** Second robotic device **620** may be associated with second robotic base **618.** In some cases, second robotic device **620** may be movably associated with second robotic base **618.** For example, second robotic device **620** may be configured to at least one of rotate or translate relative to second robotic base **618.** In some illustrative examples, second robotic base **618** may be considered part of second robotic device **620.**

[0202] As depicted, second robotic system **608** may also include second movement system **622** and second robotic controller **624.** Second movement system **622** may control the movement of at least one of second robotic device **620** relative to second robotic base **618** or second robotic base **618** relative to platform base **600.** Second movement system **622** may include at least one of an actuator device, a motor, a rail system, a track system, a slide system, a roller, a wheel, omnidirectional wheels, a pulley system, an elbow movement system, a wrist movement system, a swivel system, or an X-Y table.

[0203] Second robotic controller **624** may control the operation of second movement system **622.** For example, second movement system **622** may be comprised of one or more movement devices that may be computer numerically-controlled. Second robotic controller **624** may include, for example, without limitation, any number of control devices, computers, integrated circuits, microprocessors, other types of processing units, or combination thereof.

[0204] Both first robotic device **612** and second robotic device **620** may be internal robotic devices configured for use within interior **236** of fuselage assembly **114** in **Figure 2.** In one illustrative example, first robotic device **612** and second robotic device **620** may take the form of robotic arms. As depicted, first end effector **626** may be associated with first robotic device **612.** In some cases, first end effector **626** may be removably associated with first robotic device **612.** Second end effector **628** may be associated with second robotic device **620.** In some cases, second end effector **628** may be removably associated with second robotic device **620.** In this manner, first end effector **626** and second end effector **628** may be exchanged for other types of end effectors.

[0205] Depending on the implementation, first movement system **614** may also be used to control the movement of first end effector **626** relative to a rest of first robotic device **612.** Second movement system **622** may also be used to control the movement of second end effector **628** relative to a rest of second robotic device **620.**

[0206] As depicted, first internal tool **630** may be associated with first end effector **626** and second internal tool **632** may be associated with second end effector **628.** First internal tool **630** and second internal tool **632** may each also be referred to simply as a tool. In some illustrative examples, first internal tool **630** may be removably associated with first end effector **626** and thereby, exchangeable. Similarly, second internal tool **632** may be removably associated with second end effector **628** and thereby, exchangeable.

[0207] Depending on the implementation, each of first internal tool **630** and second internal tool **632** may be selected from one of a riveting tool, a drilling tool, a fastener insertion tool, a fastener installation tool, an inspection tool, or some other type of tool. In one illustrative example, each of first internal tool **630** and second internal tool **632** may take the form of an internal riveting tool. For example, without limitation, each of first internal tool **630** and second internal tool **632** may take the form of a bucking bar.

[0208] In this illustrative example, platform movement system **638** may be associated with platform base **600.** Platform movement system **638** may be used to drive internal mobile platform **406** along a surface or floor within interior **236** of fuselage assembly **114** in **Figure 2,** such as one of number of floors **266** in **Figure 2.** For example, platform movement system **638** may be used to move internal mobile platform **406** along first floor **623** or second floor **625.**

[0209] In this example, first floor **623** may take the form of, for example, without limitation, a passenger floor within interior **236** of fuselage assembly **114** in **Figure 1.** Further, in this example, second floor **625** may take the form of, for example, without limitation, a cargo floor within interior **236** of fuselage assembly **114** in **Figure 1.**

[0210] Platform movement system **638** may be capable of autonomously driving internal mobile platform **406.** In particular, platform movement system **638** may drive internal mobile platform **406** within interior **236** of fuselage assembly **114** to roughly position first internal tool **630** relative to a panel, such as panel **216** in **Figure 2.** This rough positioning may be referred to as macro-positioning. In this manner, first internal tool **630** may be macro-positioned **641** relative to panel **216** using platform movement system **638.**

[0211] As one illustrative example, internal mobile platform **406,** and thereby first internal tool **630,** may be macro-positioned **641** into position **633** within interior **236** of fuselage assembly **114** using platform movement system **638.** Position **633** may be a position relative to a panel of fuselage assembly **114,** such as panel **216.**

[0212] First internal tool **630** may then be micro-positioned **643** relative to particular location **635** on panel **216** within interior **236** of fuselage assembly **114.** This micro-positioning, which is a finer type of positioning, may be performed using first robotic device **612.** For example, without limitation, first movement system **614** may control at least one of first robotic device **612** or first end effector **626** associated with first robotic device **612** to micro-position first internal tool **630** at particular location **635** on panel **216.**

[0213] As depicted, assembly operation **637** may be performed at particular location **635** on panel **216.** Assembly operation **637** may be an example of one of operations **124** in **Figure 1.** In some cases, fastening process **424** in **Figure 4** may be performed at particular location **635** using first internal tool **630.**

[0214] Second internal tool **632** may be macro-positioned **641** and micro-positioned **643** in a manner similar to first internal tool **630.** In one illustrative example, first robotic controller **616** and second robotic controller **624** may control the operation of first internal tool **630** and second internal tool **632** to perform coordinated or synchronized assembly operations at the interior and exterior sides of particular location **635.**

[0215] As depicted, platform movement system **638** may take the form of track system **640.** Of course, in other illustrative examples, platform movement system **638** may include one or more other types of movement systems in addition to or in place of track system **640.** Platform movement system **638** may include, for example, without limitation, any number of actuator devices, motors, track systems, rail systems, slide systems, rollers, wheels, omnidirectional wheels, pulley systems, swivel systems, X-Y tables, other types of movement devices, or combination thereof. In yet other illustrative examples, platform movement system **638** may be implemented using an autonomous vehicle, such as one of plurality of autonomous vehicles **306** in **Figure 3.**

[0216] In this illustrative example, track system **640** includes a plurality of tracks **642.** Track **644** is an example of one of plurality of tracks **642.** Track **644** includes roller chain 648, plurality of rollers 650, and plurality of support plates 654, and may include, for example, without limitation, plurality of track wheels **646,** and plurality of track pads 652.

[0217] As depicted, plurality of rollers **650** may be associated with roller chain **648.** Plurality of rollers **650** with roller chain **648** may be moved around plurality of track wheels **646.**

[0218] Plurality of support plates **654** may be used to distribute total load **651** applied by platform base **600** and all of the components associated with platform base **600** to reduce or prevent point-loading **655** on first floor **623** or second floor **625.** In particular, plurality of rollers **650** associated with roller chain **648** may substantially evenly distribute total load **651** applied by platform base **600** and all of the components associated with platform base **600** as plurality of rollers **650** and roller chain **648** move along plurality of support plates **654** and around plurality of track wheels **646** to reduce point-loading **655.**

[0219] Plurality of track pads **652** may be associated with at least one of plurality of rollers **650** or roller chain **648.** Plurality of track pads **652** may be the portion of track **644** that contacts the surface or floor on which internal mobile platform **406** is moving.

[0220] In some illustrative examples, one or more temporary floor boards may be laid down on first floor **623** or second floor **625** of fuselage assembly **114** in **Figure 1.** Internal mobile platform **406** may be moved along these one or more temporary floor boards such that plurality of track pads **652** contact the one or more temporary floor boards instead of first floor **623** or second floor **625.**

[0221] Number of laser targets **660** may be associated with internal mobile platform **406** in this illustrative example. Number of laser targets **660** may reflect laser beams generated by, for example, without limitation, laser tracking system **137** in **Figure 1.** Laser tracking system **137** in **Figure 1** may use the reflected laser beams to generate data that may be used to control at least one of platform movement system **638,** first movement system **614,** second movement system **622,** or some other type of movement system associated with internal mobile platform **406.**

[0222] In this manner, number of laser targets **660** may be used for driving and roughly positioning internal mobile platform **406** within fuselage assembly **114,** and thereby macro-positioning first internal tool **630** and second internal tool **632.** Further, number of laser targets **660** may be used to micro-position first internal tool **630** and second internal tool **632.**

[0223] Depending on the implementation, each of number of laser targets **660** may be associated with platform base **600** either directly or indirectly. As one illustrative example, number of laser targets **660** may be associated with platform base **600** indirectly through frame **661,** which may be directly associated with platform base **600.** For example, number of laser targets **660** may be positioned on frame **661** such that number of laser targets **660** may be in the field of view of laser tracking system **657** associated with robotics tower **601.**

[0224] Set of units **662** may also be associated with platform base **600.** Set of units **662** may include any number of control units, power units, interfaces, coupling units, hydraulic units, air units, other types of units, or some combination thereof needed for the operation of internal mobile platform **406** and number of robotic systems **602.**

[0225] In this illustrative example, set of units **662** may be configured to receive number of utilities **146** through number of utility cables **664.** Number of utility cables **664** may extend from cable management system **665** associated with robotics tower **601.** Robotics tower **601** may be an example of one implementation for second tower **336** in **Figure 3.**

[0226] Number of utility cables **664** may provide number of utilities **146** to set of units **662,** which may distribute number of utilities **146** to number of robotic systems **602** and the various other components that make up internal mobile platform **406.** In other illustrative examples, one or more of number of utility cables **664** may connect directly to one or more components in number of robotic systems **602.**

[0227] In this manner, internal mobile platform **406** may be configured to receive number of utilities **146** from robotics tower **601** rather than having to connect separately to some other number of utility sources. Further, by cable management system **665** managing number of utility cables **664,** the additional weight, or load, applied to internal mobile platform **406** by number of utility cables **664** may be reduced. Cable management system **665** may keep number of utility cables **664** organized such that number of utility cables **664** do not become entangled or otherwise disorganized in a manner that impedes operation of internal mobile platform **406.** In some cases, cable management system **665** may use a biasing system to keep number of utility cables **664** in tension.

[0228] Internal mobile platform **406** may be positioned on one of first platform level **615** and second platform level **617** of robotics tower **601** in **Figure 6** when not in use. Internal mobile platform **406** may be driven from robotics tower **601** into fuselage assembly **114.** In particular, robotics tower **601** may be positioned relative to assembly fixture **324** in **Figure 3.** A number of platform levels of robotics tower **601** may be mated to number of floors **266** of fuselage assembly **114** shown in **Figure 2.** Internal mobile platform **406** may be autonomously driven from one of the number of platform levels of robotics tower **601** onto a corresponding one of number of floors **266** in **Figure 2.**

[0229] For example, without limitation, internal mobile platform **406** may be driven from first platform level **615** of robotics tower **601** onto first floor **623** inside fuselage assembly **114.** As another example, internal mobile platform **406** may be driven from second platform level **617** of robotics tower **601** onto second floor **625** inside fuselage assembly **114.**

[0230] In these illustrative examples, the various systems and devices used to move platform base **600** of internal mobile platform **406** relative to one of number of floors **266** in **Figure 2** as described above may be collectively referred to as macro-positioning system **611.** Macro-positioning system **611** may be associated with internal mobile platform **406** and used to move platform base **600** with at least one degree of freedom relative to one of number of floors **266** in **Figure 2.** Macro-positioning system **611** may include at least one of platform movement system **638** or some other type of movement, positioning, or rough adjustment system.

[0231] Similarly, the various systems and devices used to move first internal tool **630** and second internal tool **632** relative to platform base **600** of internal mobile platform **406** as described above may be collectively referred to as micro-positioning system **613.** Micro-positioning system **613** may be associated with internal mobile platform **406** and used to move each of first internal tool **630** and second internal tool **632** with at least one degree of freedom relative to platform base **600** of internal mobile platform **406.** Micro-positioning system **613** may include at least one of first robotic device **612,** first movement system **614,** second robotic device **620,** second movement system **622,** or some other type of movement system, positioning system, or fine adjustment system.

[0232] The illustrations in **Figures 1-6** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

[0233] For example, in some cases, more than one flexible manufacturing system may be present within manufacturing environment **100.** These multiple flexible manufacturing systems may be used to build multiple fuselage assemblies within manufacturing environment **100.** In other illustrative examples, flexible manufacturing system **106** may include multiple cradle systems, multiple tower systems, multiple utility systems, multiple autonomous tooling systems, and multiple pluralities of autonomous vehicles such that multiple fuselage assemblies may be built within manufacturing environment **100.**

[0234] In some illustrative examples, utility system **138** may include multiple utility fixtures that are considered separate from flexible manufacturing system **106.** Each of these multiple utility fixtures may be configured for use with flexible manufacturing system **106** and any number of other flexible manufacturing systems.

[0235] Additionally, the different couplings of mobile systems in plurality of mobile systems **134** may be performed autonomously in these illustrative examples. However, in other illustrative example, a coupling of one of plurality of mobile systems **134** to another one of plurality of mobile systems **134** may be performed manually in other illustrative examples.

[0236] Further, in other illustrative examples, one or more of plurality of mobile systems **134** may be drivable by, for example, without limitation, a human operator. For example, without limitation, in some cases, first tower **332** may be drivable with human guidance.

[0237] With reference now to **Figure 7,** an illustration of an isometric view of a manufacturing environment is depicted in accordance with an illustrative embodiment. In this illustrative example, manufacturing environment **700** may be an example of one implementation for manufacturing environment **100** in **Figure 1.**

[0238] As depicted, manufacturing environment **700** may include holding environment **701** and assembly environment **702.** Holding environment **701** may be a designated area on and over floor **703** of manufacturing environment **700** for storing plurality of flexible manufacturing systems **706** when plurality of flexible manufacturing systems **706** are not in use. Each of plurality of flexible manufacturing systems **706** may be an example of one implementation for flexible manufacturing system **106** described in **Figures 1** and **3-5.** In particular, each of plurality of flexible manufacturing systems **706** may be an example of one implementation for autonomous flexible manufacturing system **112** in **Figure 1.**

[0239] Holding environment **701** may include plurality of holding cells **704.** In this illustrative example, each of plurality of holding cells **704** may be considered an example of one implementation for holding area **318** in **Figure 3.** In other illustrative examples, the entire holding environment **701** may be considered an example of one implementation for holding area **318** in **Figure 3.**

[0240] Each of plurality of flexible manufacturing systems **706** may be stored in a corresponding one of plurality of holding cells **704.** In particular, each of plurality of holding cells **704** may be designated for a specific one of plurality of flexible manufacturing systems **706.** However, in other illustrative examples, any one of plurality of holding cells **704** may be used for storing any one of plurality of flexible manufacturing systems **706.**

[0241] As depicted, flexible manufacturing system **708** may be an example of one of plurality of flexible manufacturing systems **706.** Flexible manufacturing system **708** may include plurality of mobile systems **711,** which may be an example of one implementation for plurality of mobile systems **134** in **Figures 1** and **3.**

[0242] Flexible manufacturing system **708** may be stored in holding cell **710** of plurality of holding cells **704.** In this example, all of holding environment **701** may be considered an example of one implementation for holding area **318** in **Figure 3.** However, in other examples, each of plurality of holding cells **704** in holding environment **701** may be considered an example of one implementation for holding area **318** in **Figure 3.**

[0243] Floor **703** of manufacturing environment **700** may be substantially smooth to allow the various components and systems of plurality of flexible manufacturing systems **706** to be autonomously driven across floor **703** of manufacturing environment **700** with ease. When one of plurality of flexible manufacturing systems **706** is ready for use, that flexible manufacturing system may be driven across floor **703** from holding environment **701** into assembly environment **702.**

[0244] Assembly environment **702** may be the designated area on and above floor **703** for building fuselage assemblies. When none of plurality of flexible manufacturing systems **706** are in use, floor **703** of assembly environment **702** may be kept substantially open and substantially clear.

[0245] As depicted, assembly environment **702** may include plurality of work cells **712.** In one illustrative example, each of plurality of work cells **712** may be an example of one implementation for assembly area **304** in **Figure 3.** Thus, each of plurality of work cells **712** may be designated for performing a fuselage assembly process, such as assembly process **110** in **Figure 1,** for building fuselage assembly **114** in **Figure 1.** In other illustrative examples, the entire assembly environment **702** may be considered an example of one implementation for assembly area **304** in **Figure 3.**

[0246] In this illustrative example, first portion **714** of plurality of work cells **712** may be designated for building forward fuselage assemblies, such as forward fuselage assembly **117** in **Figure 1,** while second portion **716** of plurality of work cells **712** may be designated for building aft fuselage assemblies, such as aft fuselage assembly **116** in **Figure 1.** In this manner, plurality of work cells **712** may allow multiple fuselage assemblies to be built concurrently. Depending on the implementation, the building of these fuselage assemblies may begin at the same time or at different times in plurality of work cells **712.**

[0247] In one illustrative example, plurality of mobile systems **711** that belong to flexible manufacturing system **708** may be driven across floor **703** from holding cell **710** into work cell **713.** Within work cell **713,** plurality of mobile systems **711** may be used to build a fuselage assembly (not shown). An example of one manner in which this fuselage assembly may be built using flexible manufacturing system **708** is described in greater detail in **Figures 8-18** below.

[0248] In some illustrative examples, a sensor system may be associated with one or more of plurality of work cells **712.** For example, without limitation, in some cases, sensor system **718** may be associated with work cell **719** of plurality of work cells **712.** Sensor data generated by sensor system **718** may be used to help drive the various mobile systems of the corresponding one of plurality of flexible manufacturing systems **706** designated for building a fuselage assembly within work cell **719.** In one illustrative example, sensor system **718** may take the form of metrology system **720.**

[0249] Depending on the implementation, sensor system **718** may be optional. For example, without limitation, other sensor systems are not depicted associated with other work cells of plurality of work cells **712.** Not using sensors systems such as sensor system **718** may help keep floor **703** of manufacturing environment **700** more open and clear to help the various mobile systems of plurality of flexible manufacturing systems **706** be driven more freely across floor **703.**

[0250] As depicted, plurality of utility fixtures **724** may be permanently affixed to floor **703.** Each of plurality of utility fixtures **724** may be an example of one implementation for utility fixture **150** in **Figure 1.**

[0251] Plurality of utility fixtures **724** may be interfaced with a number of utility sources (not shown in this view). These utility sources (not shown) may be, for example, without limitation, located beneath floor **703.** Utility fixture **726** may be an example of one of plurality of utility fixtures **724.**

[0252] In this illustrative example, each of plurality of utility fixtures **724** is located in a corresponding one of plurality of work cells **712.** Any one of plurality of flexible manufacturing systems **706** may be driven towards and interfaced with any one of plurality of utility fixtures **724.** In this manner, plurality of utility fixtures **724** may be used to provide one or more utilities to plurality of flexible manufacturing systems **706.**

[0253] Referring now to **Figures 8-18,** illustrations of the building of a fuselage assembly within manufacturing environment **700** from **Figure 7** are depicted in accordance with an illustrative embodiment. In **Figures 8-18,** flexible manufacturing system **708** from **Figure 7** may be used to build a fuselage assembly. The building of the fuselage assembly may be performed within any one of plurality of work cells **712** in **Figure 7.** For example, without limitation, the building of the fuselage assembly may be performed within one of the work cells in second portion **716** of plurality of work cells **712** in **Figure 7.**

[0254] Turning now to **Figure 8,** an illustration of an isometric view of a first tower coupled to utility fixture **726** from **Figure 7** is depicted in accordance with an illustrative embodiment. In this illustrative example, first tower **800** may be coupled to utility fixture **726.** First tower **800** may be an example of one of plurality of mobile systems **711** of flexible manufacturing system **708** in **Figure 7**. In particular, first tower **800** may be an example of one implementation for first tower **334** in **Figure 3.**

[0255] First tower **800** may be at least one of electrically and physically coupled to utility fixture **726** such that interface **802** is formed between first tower **800** and utility fixture **726.** Interface **802** may be an example of one implementation for interface **342** in **Figure 3.**

[0256] As depicted, first tower **800** may have base structure **804.** Base structure **804** may include top platform **806** and bottom platform **807.** In some cases, top platform **806** and bottom platform **807** may be referred to as top platform level and a bottom platform level, respectively. Top platform **806** may be used to provide a human operator with access to a top floor of a fuselage assembly (not shown), such as a passenger floor inside the fuselage assembly. Bottom platform **807** may be used to provide a human operator with access to a bottom floor of the fuselage assembly (not shown), such as a cargo floor inside the fuselage assembly.

[0257] In this illustrative example, walkway **808** may provide access from a floor, such as floor **703** in **Figure 7,** to bottom platform **807.** Walkway **810** may provide access from bottom platform **807** to top platform **806.** Railing **812** is associated with top platform **806** for the protection of a human operator moving around on top platform **806.** Railing **814** is associated with bottom platform **807** for the protection of a human operator moving around on bottom platform **807.**

[0258] First tower **800** may be autonomously driven across floor **703** using autonomous vehicle **816.** Autonomous vehicle **816** may be an automated guided vehicle (AGV) in this example. Autonomous vehicle **816** may be an example of one of plurality of autonomous vehicles **306** in **Figure 3.** As depicted, autonomous vehicle **816** may be used to drive first tower **800** from holding environment **701** in **Figure** 7 to selected tower position **818**

relative to utility fixture **726.** Selected tower position **818** may be an example of one implementation for selected tower position **338** in **Figure 3.**

[0259] Once first tower **800** has been autonomously driven into selected tower position **818,** first tower **800** may autonomously couple to utility fixture **726.** In particular, first tower **800** may electrically and physically couple to utility fixture **726** autonomously to form interface **802.** This type of coupling may enable a number of utilities to flow from utility fixture **726** to first tower **800.** In this manner, first tower **800** and utility fixture **726** may establish at least a portion of a distributed utility network, similar to distributed utility network **144** described in **Figures 1** and **5.**

[0260] With reference now to **Figure 9,** an illustration of an isometric view of a cradle system is depicted in accordance with an illustrative embodiment. In this illustrative example, cradle system **900** may be an example of one implementation for cradle system **308** in **Figure 3.** Further, cradle system **900** may be an example of one of plurality of mobile systems **711** of flexible manufacturing system **708** in **Figure 7.** In this manner, cradle system **900** may be an example of one of plurality of mobile systems **711** that are stored in holding cell **710** in **Figure 7.**

[0261] As depicted, cradle system **900** may be comprised of number of fixtures **903.** Number of fixtures **903** may be an example of one implementation for number of fixtures **313** in **Figure 3.** Number of fixtures **903** may include number of cradle fixtures **902** and fixture **904.** Number of cradle fixtures **902** may be an example of one implementation for number of cradle fixtures **314** in **Figure 3.**

[0262] Number of cradle fixtures **902** may include cradle fixture **906,** cradle fixture **908,** and cradle fixture **910.** Fixture **904** may be fixedly associated with cradle fixture **906.** In this illustrative example, fixture **904** may be considered part of cradle fixture **906.** However, in other illustrative examples, fixture **904** may be considered a separate fixture from cradle fixture **906.**

[0263] As depicted, cradle fixture **906,** cradle fixture **908,** and cradle fixture **910** have base **912,** base **914,** and base **916,** respectively. Number of retaining structures **918** may be associated with base **912.** Number of retaining structures **920** may be associated with base **914.** Number of retaining structures **922** may be associated with base **916.** Each of number of retaining structures **918,** number of retaining structures **920,** and number of retaining structures **922** may be an example of an implementation for number of retaining structures **326** in **Figure 3.**

[0264] Each retaining structure in number of retaining structures **918,** number of retaining structures **920,** and number of retaining structures **922** may have a curved shape that substantially matches a curvature of a corresponding fuselage section to be received by the retaining structure. Retaining structure **923** may be an example of one of number of retaining structures **920.** As depicted, retaining structure **923** may have curved shape **925.**

[0265] Curved shape **925** may be selected such that curved shape **925** substantially matches a curvature of a corresponding keel panel (not shown) that is to be engaged with retaining structure **923.** More specifically, retaining structure **923** may have a substantially same radius of curvature as a corresponding keel panel (not shown) that is to be engaged with retaining structure **923.**

[0266] In this illustrative example, plurality of stabilizing members **924,** plurality of stabilizing members **926,** and plurality of stabilizing members **928** may be associated with base **912,** base **914,** and base **916,** respectively. Plurality of stabilizing members **924,** plurality of stabilizing members **926,** and plurality of stabilizing members **928** may be used to stabilize base **912,** base **914,** and base **916,** respectively, relative to floor **703** of manufacturing environment **700.**

[0267] In one illustrative example, these stabilizing members may keep their respective bases substantially level relative to floor **703.** Further, each of plurality of stabilizing members **924,** plurality of stabilizing members **926,** and plurality of stabilizing members **928** may substantially support their respective base until that base is to be moved to a new location within or outside of manufacturing environment **700.** In one illustrative example, each stabilizing member of plurality of stabilizing members **924,** plurality of stabilizing members **926,** and plurality of stabilizing members **928** may be implemented using a hydraulic leg.

[0268] Each of number of fixtures **903** may be used to support and hold a corresponding fuselage section (not shown) for a fuselage assembly (not shown) for an aircraft (not shown), such as one of plurality of fuselage sections **205** for fuselage assembly **114** for aircraft **104** in **Figure 2.** For example, without limitation, fixture **904** may have platform **930** associated with base **932.** Platform **930** may be configured to support and hold a forward fuselage section (not shown) or an aft fuselage section (not shown) for the aircraft (not shown), depending on the implementation. The forward fuselage section (not shown) may be the portion of the fuselage assembly (not shown) that is to be closest to the nose of the aircraft (not shown). The aft fuselage section (not shown) may be the portion of the fuselage assembly (not shown) that is to be closest to the tail of the aircraft (not shown).

[0269] With reference now to **Figure 10,** an illustration of an isometric view of an assembly fixture formed using cradle system **900** from **Figure 9** and coupled to first tower **800** from **Figure 8** is depicted in accordance with an illustrative embodiment. In this illustrative example, cradle fixture **910** is coupled to first tower **800** and cradle fixture **910,** cradle fixture **906,** and cradle fixture **908** are coupled to each other.

[0270] Cradle fixture **910,** cradle fixture **908,** and cradle fixture **906** may have been autonomously driven across floor **703** of manufacturing environment **700** to selected cradle position **1000,** selected cradle position **1002,** and selected cradle position **1004,** respectively, using a number of corresponding autonomous vehicles (not shown), such as number of corresponding autonomous vehicles **316** from **Figure 3.** Driving cradle fixture **906** may also cause fixture **904** to be driven when fixture **904** is part of cradle fixture **906** as shown. Selected cradle position **1000,** selected cradle position **1002,** and selected cradle position **1004** may be an example of one implementation for number of selected cradle positions **320** in **Figure 3.**

[0271] After driving cradle fixture **910,** cradle fixture **908,** and cradle fixture **906** to selected cradle position **1000,** selected cradle position **1002,** and selected cradle position **1004,** respectively, the number of corresponding autonomous vehicles (not shown) may be autonomously driven away. In other illustrative examples, the number of corresponding autonomous vehicles (not shown) may be integrated as part of cradle fixture **910,** cradle fixture **908,** and cradle fixture **906.**

[0272] Selected cradle position **1000** may be a position relative to selected tower position **818** of first tower **800.** When cradle fixture **910** is in selected cradle position **1000** relative to first tower **800,** cradle fixture **910** may be electrically and physically coupled to first tower **800** to form interface **1006.** In some cases, cradle fixture **910** may be coupled to first tower **800** autonomously to form interface **1006.** In one illustrative example, interface **1006** may be formed by autonomously coupling cradle fixture **910** to first tower **800.** Interface **1006** may be an electrical and physical interface that enables a number of utilities that are flowing from utility fixture **726** to first tower **800** to also flow to cradle fixture **910.** In this manner, interface **1006** may be formed by autonomously coupling a number of utilities between cradle fixture **910** and first tower **800.** Interface **1006** may be an example of one implementation for interface **340** in **Figure 3.** In this illustrative example, cradle fixture **910,** being coupled to first tower **800,** may be referred to as primary cradle fixture **1011.**

[0273] Further, as depicted, cradle fixture **906,** cradle fixture **908,** and cradle fixture **910** may be coupled to each other. In particular, cradle fixture **908** may be coupled to cradle fixture **910** to form interface **1008.** Similarly, cradle fixture **906** may be coupled to cradle fixture **908** to form interface **1010.** In one illustrative example, both interface **1008** and interface **1010** may be formed by autonomously coupling these cradle fixtures to each other.

[0274] In particular, interface **1008** and interface **1010** may take the form of electrical and physical interfaces that enable the number of utilities to flow from cradle fixture **910,** to cradle fixture **908,** and to cradle fixture **906.** In this manner, interface **1008** may be formed by autonomously coupling the number of utilities between cradle fixture **910** and cradle fixture **908** and interface **1010** may be formed by autonomously coupling the number of utilities between cradle fixture **908** and cradle fixture **906.** In this manner, number of utilities **146** may be autonomously coupled between adjacent cradle fixtures in number of cradle fixtures **314.**

[0275] Thus, when utility fixture **726,** first tower **800,** cradle fixture **910,** cradle fixture **908,** and cradle fixture **906** are all coupled in series as described above, the number of utilities may be distributed downstream from utility fixture **726** to first tower **800,** cradle fixture **910,** cradle fixture **908,** and cradle fixture **906.** In this illustrative example, any utilities that flow to cradle fixture **906** may also be distributed to fixture **904.**

[0276] Any number of coupling units, structural members, connection devices, cables, other types of elements, or combination thereof may be used to form interface **1008** and interface **1010.** Depending on the implementation, interface **1008** and interface **1010** may take the form of coupling units that both physically and electrically connect cradle fixture **910,** cradle fixture **908,** and cradle fixture **906** to each other. In other illustrative examples, interface **1008** and interface **1010** may be implemented in some other manner.

[0277] When cradle fixture **910,** cradle fixture **908,** and cradle fixture **906** are in selected cradle position **1000,** selected cradle position **1002,** and selected cradle position **1004,** respectively, and coupled to each other, these cradle fixtures together form assembly fixture **1012.** Assembly fixture **1012** may be an example of one implementation for assembly fixture **324** in **Figure 3.** In this manner, interface **1006** between first tower **800** and cradle fixture **910** may also be considered an electrical and physical interface between first tower **800** and assembly fixture **1012.**

[0278] With reference now to **Figure 11,** an illustration of an isometric view of one stage in the assembly process for building a fuselage assembly that is being supported by assembly fixture **1012** from **Figure 10** is depicted in accordance with an illustrative embodiment. In this illustrative example, assembly fixture **1012** may support fuselage assembly **1100** as fuselage assembly **1100** is built on assembly fixture **1012.**

[0279] Fuselage assembly **1100** may be an aft fuselage assembly that is an example of one implementation for aft fuselage assembly **116** in **Figure 1.** Fuselage assembly **1100** may be partially assembled in this illustrative example. Fuselage assembly **1100** may be at an early stage of assembly in this example.

[0280] At this stage of the assembly process, fuselage assembly **1100** includes end panel **1101** and plurality of keel panels **1102.** End panel **1101** may have a tapered cylindrical shape in this illustrative example. In this manner, one portion of end panel **1101** may form part of the keel **1105** for fuselage assembly **1100,** another portion of end panel **1101** may form part of the sides (not fully shown) for fuselage assembly **1100,** and yet another portion of end panel **1101** may form part of a crown (not fully shown) for fuselage assembly **1100.**

[0281] Further, as depicted, bulkhead **1103** may be associated with end panel **1101.** Bulkhead **1103** may be a pressure bulkhead. Bulkhead **1103** may be an example of one implementation for bulkhead **272** in **Figure 2.**

[0282] Plurality of keel panels **1102** include keel panel **1104,** keel panel **1106,** and keel panel **1108.** End panel **1101** and plurality of keel panels **1102** have been engaged with assembly fixture **1012.** In particular, end panel **1101** has been engaged with fixture **904.** Keel panel **1104,** keel panel **1106,** and keel panel **1108** have been engaged with cradle fixture **906,** cradle fixture **908,** and cradle fixture **910,** respectively.

[0283] In one illustrative example, end panel **1101** is first engaged with fixture **904** with keel panel **1104,** keel panel **1106,** and keel panel **1108** then being successively engaged with cradle fixture **906,** cradle fixture, **908,** and cradle fixture **910,** respectively. In this manner, keel **1105** of fuselage assembly **1100** may be assembled in a direction from the aft end of fuselage assembly **1100** to the forward end of fuselage assembly **1100.**

[0284] Each of cradle fixture **906,** cradle fixture **908,** and cradle fixture **910** may be at least one of autonomously or manually adjusted, as needed, to accommodate plurality of keel panels **1102** such that fuselage assembly **1100** may be built to meet outer mold line requirements and inner mold line requirements within selected tolerances. In some cases, at least one of cradle fixture **906,** cradle fixture **908,** and cradle fixture **910** may have at least one retaining structure that can be adjusted to adapt to the shifting of fuselage assembly **1100** during the assembly process due to increased loading as fuselage assembly **1100** is built.

[0285] As depicted, members **1111** may be associated with end panel **1101** and plurality of keel panels **1102.** Members **1111** may include frames and stringers in this illustrative example. However, depending on the implementation, members **1111** may also include, without limitation, stiffeners, stanchions, intercostal structural members, connecting members, other types of structural members, or some combination thereof. The connecting members may include, for example, without limitation, shear clips, ties, splices, intercostal connecting members, other types of mechanical connecting members, or some combination thereof.

[0286] The portion of members **1111** attached to end panel **1101** may form support section **1110.** The portions of members **1111** attached to keel panel **1104,** keel panel **1106,** and keel panel **1108** may form support section **1112,** support section **1114,** and support section **1116,** respectively.

[0287] In this illustrative example, end panel **1101** may form fuselage section **1118** for fuselage assembly **1100.** Each of keel panel **1104,** keel panel **1106,** and keel panel **1108** may form a portion of fuselage section **1120,** fuselage section **1122,** and fuselage section **1124,** respectively, for fuselage assembly **1100.** Fuselage section **1118,** fuselage section **1120,** fuselage section **1122,** and fuselage section **1124** may together form plurality of fuselage sections **1125** for fuselage assembly **1100.** Each of fuselage section **1118,** fuselage section **1120,** fuselage section **1122,** and fuselage section **1124** may be an example of one implementation for fuselage section **207** in **Figure 2.**

[0288] End panel **1101** and plurality of keel panels **1102** may be temporarily connected together using temporary fasteners such as, for example, without limitation, tack fasteners. In particular, end panel **1101** and plurality of keel panels **1102** may be temporarily connected to each other as each of the panels is engaged with assembly fixture **1012** and other panels.

[0289] For example, without limitation, coordination holes (not shown) may be present at the edges of end panel **1101** and each of plurality of keel panels **1102.** In some cases, a coordination hole may pass through a panel and at least one of members **1111** associated with the panel. Engaging one panel with another panel may include aligning these coordination holes such that temporary fasteners, such as tack fasteners, may be installed in these coordination holes. In some cases, engaging one panel with another panel may include aligning a coordination hole through one panel with a coordination hole through one of members **1111** associated with another panel.

[0290] In yet another illustrative example, engaging a first panel with another panel may include aligning the edges of the two panels to form a butt splice. These two panels may then be temporarily connected together by aligning a first number of coordination holes in, for example, a splice plate, with a corresponding number of holes on the first panel and aligning a second number of coordination holes in that splice plate with a corresponding number of holes on the second panel. Temporary fasteners may then be inserted through these aligned coordination holes to temporarily connect the first panel to the second panel.

[0291] In this manner, panels and members may be engaged with each other and temporarily connected together in a number of different ways. Once end panel **1101** and plurality of keel panels **1102** have been temporarily connected together, assembly fixture **1012** may help maintain the position and orientation of end panel **1101** and each of plurality of keel panels **1102** relative to each other.

[0292] Turning now to **Figure 12,** an illustration of an isometric view of another stage in the assembly process for building a fuselage assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, cargo floor **1200** has been added to fuselage assembly **1100.** In particular, cargo floor **1200** may be associated with plurality of keel panels **1102.**

[0293] As depicted, at least a portion of cargo floor **1200** may be substantially level with bottom platform **807** of first tower **800.** In particular, at least the portion of cargo floor **1200** nearest first tower **800** may be substantially aligned with bottom platform **807** of first tower **800.** In this manner, a human operator (not shown) may use bottom platform **807** of first tower **800** to easily walk onto cargo floor **1200** and access interior **1201** of fuselage assembly **1100.**

[0294] As depicted, first side panels **1202** and second side panels **1204** have been added to fuselage assembly **1100.** First side panels **1202** and second side panels **1204** may be an example of one implementation for first side panels **224** and second side panels **226,** respectively, in **Figure 2.** First side panels **1202,** second side panels **1204,** and a first and second portion of end panel **1101** may form sides **1205** of fuselage assembly **1100.** In this illustrative example, plurality of keel panels **1102,** end panel **1101,** first side panels **1202,** and second side panels **1204** may all be temporarily connected together using, for example, without limitation, tack fasteners.

[0295] First side panels **1202** may include side panel **1206,** side panel **1208,** and side panel **1210** that have been engaged with and temporarily connected to keel panel **1104,** keel panel **1106,** and keel panel **1108,** respectively. Similarly, second side panels **1204** may include side panel **1212,** side panel **1214,** and side panel **1216** that have been engaged with and temporarily connected to keel panel **1104,** keel panel **1106,** and keel panel **1108,** respectively. Further, both side panel **1206** and side panel **1212** have been engaged with end panel **1101.**

[0296] As depicted, members **1218** may be associated with first side panels **1202.** Other members (not shown) may be similarly associated with second side panels **1204.** Members **1218** may be implemented in a manner similar to members **1111.** In this illustrative example, corresponding portion **1220** of members **1218** may be associated with side panel **1206.** Corresponding portion **1220** of members **1218** may form support section **1222** associated with side panel **1206.** Support section **1222** may be an example of one implementation for support section **238** in **Figure 2.**

[0297] With reference now to **Figure 13,** an illustration of an isometric view of another stage in the assembly process for building a fuselage assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, passenger floor **1300** has been added to fuselage assembly **1100.** As depicted, passenger floor **1300** may be substantially level with top platform **806** of first tower **800.** Human operator **1302** may use top platform **806** of first tower **800** to walk onto passenger floor **1300** and access interior **1201** of fuselage assembly **1100.**

[0298] With reference now to **Figure 14,** an illustration of an isometric view of another stage in the assembly process for building a fuselage assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, plurality of crown panels **1400** have been added to fuselage assembly **1100.** Plurality of crown panels **1400** may be an example of one implementation for crown panels **218** in **Figure 2.**

[0299] In this illustrative example, plurality of crown panels **1400** may include crown panel **1402,** crown panel **1404,** and crown panel **1406.** These crown panels along with a top portion of end panel **1101** may form crown **1407** of fuselage assembly **1100.** Crown panel **1402** may be engaged with and temporarily connected to end panel **1101,** side panel **1206** shown in **Figure 12,** side panel **1212,** and crown panel **1404.** Crown panel **1404** may be engaged with and temporarily connected to crown panel **1402,** crown panel **1406,** side panel **1208** shown in **Figure 12,** and side panel **1214.** Further, crown panel **1406** may be engaged with and temporarily connected to crown panel **1404,** side panel **1210,** and side panel **1216.**

[0300] Together, end panel **1101,** plurality of keel panels **1102,** first side panels **1202,** second side panels **1204,** and plurality of crown panels **1400** may form plurality of panels **1408** for fuselage assembly **1100.** Plurality of panels **1408** may be an example of one implementation for plurality of panels **120** in **Figure 1.**

[0301] Plurality of panels **1408** may all be temporarily connected to each other such that desired compliance with outer mold line requirements and inner mold line requirements may be maintained during the building of fuselage assembly **1100.** In other words, temporarily connecting plurality of panels **1408** to each other may enable outer mold line requirements and inner mold line requirements to be met within selected tolerances during the building of fuselage assembly **1100** and, in particular, the joining of plurality of panels **1408** together.

[0302] Members (not shown) may be associated with plurality of crown panels **1400** in a manner similar to the manner in which members **1218** are associated with first side panels **1202.** These members associated with plurality of crown panels **1400** may be implemented in a manner similar to members **1218** and members **1111** as shown in **Figures 12-13.** The various members associated with end panel **1101,** plurality of keel panels **1102,** plurality of crown panels **1400,** first side panels **1202,** and second side panels **1204** may form plurality of members **1410** for fuselage assembly **1100.** When plurality of panels **1408** are joined together, plurality of members **1410** may form a support structure (not yet shown) for fuselage assembly **1100,** similar to support structure **131** in **Figure 1.**

[0303] After plurality of crown panels **1400** have been added to fuselage assembly **1100,** first tower **800** may be autonomously decoupled from assembly fixture **1012** and utility fixture **726.** First tower **800** may then be autonomously driven away from utility fixture **726** using, for example, without limitation, autonomous vehicle **816** in **Figure 8.** In one illustrative example, first tower **800** may be autonomously driven back to holding environment **701** in **Figure 7.**

[0304] When first tower **800** is decoupled from assembly fixture **1012** and utility fixture **726,** a gap is formed in the distributed utility network. This gap may be filled using a second tower (not shown), implemented in a manner similar to second tower **336** in **Figure 3.**

[0305] With reference now to **Figure 15,** an illustration of an isometric view of a second tower coupled to utility fixture **726** and assembly fixture **1012** supporting fuselage assembly **1100** from **Figure 14** is depicted in accordance with an illustrative embodiment. In this illustrative example, second tower **1500** has been positioned relative to assembly fixture **1012** and utility fixture **726.** Second tower **1500** may be an example of one implementation for second tower **336** in **Figure 3.**

[0306] Second tower **1500** may be autonomously driven across floor **703** using an autonomous vehicle (not shown), similar to autonomous vehicle **816** in **Figure 8.** Second tower **1500** may be autonomously driven into selected tower position **1518** relative to utility fixture **726.** Selected tower position **1518** may be an example of one implementation for selected tower position **338** in **Figure 3.** In this illustrative example, selected tower position **1518** may be substantially the same as selected tower position **818** in **Figure 8.**

[0307] Once second tower **1500** has been autonomously driven into selected tower position **1518,** second tower **1500** may autonomously couple to utility fixture **726.** In particular, second tower **1500** may electrically and physically couple to utility fixture **726** autonomously to form interface **1502.** Interface **1502** may be another example of one implementation for interface **342** in **Figure 3.** This type of coupling may enable a number of utilities to flow from utility fixture **726** to second tower **1500.**

[0308] Further, second tower **1500** may autonomously couple to cradle fixture **910**, thereby autonomously coupling to assembly fixture **1012,** to form interface **1505.** Interface **1505** may enable the number of utilities to flow downstream from second tower **1500.** In this manner, the number of utilities may flow from second tower **1500** to cradle fixture **910,** to cradle fixture **908,** and then to cradle fixture **906.** In this manner, second tower **1500** may fill the gap in the distributed utility network that was created when first tower **800** in **Figure 14** was decoupled from assembly fixture **1012** and utility fixture **726** and driven away.

[0309] Similar to first tower **800** in **Figure 8,** second tower **1500** may include base structure **1504,** top platform **1506,** and bottom platform **1507.** However, top platform **1506** and bottom platform **1507** may be used to provide internal mobile platforms with access to interior **1201** of fuselage assembly **1100** instead of human operators.

[0310] In this illustrative example, internal mobile platform **1508** may be positioned on top platform **1506.** Top platform **1506** may be substantially aligned with passenger floor **1300** such that internal mobile platform **1508** may be able to autonomously drive across top platform **1506** onto passenger floor **1300.**

[0311] Similarly, an internal mobile platform (not shown in this view) may be positioned on bottom platform **1507.** Bottom platform **1507** may be substantially aligned with cargo floor **1200** (not shown in this view) from **Figure 12** such that this other internal mobile platform (not shown in this view) may be able to autonomously drive across bottom platform **1507** onto the cargo floor. Internal mobile platform **1508** and the other internal mobile platform (not shown in this view) may be examples of implementations for internal mobile platform **406** in **Figure 4.**

[0312] As depicted, internal robotic device **1510** and internal robotic device **1512** may be associated with internal mobile platform **1508.** Although internal robotic device **1510** and internal robotic device **1512** are shown associated with the same internal mobile platform **1508,** in other illustrative examples, internal robotic device **1510** may be associated with one internal mobile platform and internal robotic device **1512** may be associated with another internal mobile platform. Each of internal robotic device **1510** and internal robotic device **1512** may be an example of one implementation for internal robotic device **416** in **Figure 4.**

[0313] Internal robotic device **1510** and internal robotic device **1512** may be used to perform operations within interior **1201** of fuselage assembly **1100** for joining plurality of panels **1408.** For example, without limitation, internal robotic device **1510** and internal robotic device **1512** may be used to perform fastening operations, such as riveting operations, within interior **1201** of fuselage assembly **1100.**

[0314] In one illustrative example, utility box **1520** may be associated with base structure **1504.** Utility box **1520** may manage the number of utilities received from utility fixture **726** through interface **1502** and may distribute these utilities into utility cables that are managed using cable management system **1514** and cable management system **1516.**

[0315] As depicted in this example, cable management system **1514** may be associated with top platform **1506** and cable management system **1516** may be associated with bottom platform **1507.** Cable management system **1514** and cable management system **1516** may be implemented similarly.

[0316] Cable management system **1514** may include cable wheels **1515** and cable management system **1516** may include cable wheels **1517.** Cable wheels **1515** may be used to spool utility cables that are connected to internal mobile platform **1508.** For example, without limitation, cable wheels **1515** may be biased in some manner to substantially maintain a selected amount of tension in the utility cables. This biasing may be achieved using, for example, one or more spring mechanisms.

[0317] As internal mobile platform **1508** moves away from second tower **1500** along passenger floor **1300,** the utility cables may extend from cable wheels **1515** to maintain utility support to internal mobile platform **1508** and manage the utility cables such that they do not become tangled. Cable wheels **1517** may be implemented in a manner similar to cable wheels **1515.**

[0318] By using cable wheels **1515** to spool the utility cables, the utility cables may be kept off of internal mobile platform **1508,** thereby reducing the weight of internal mobile platform **1508** and the load applied by internal mobile platform **1508** to passenger floor **1300.** The number of utilities provided to internal mobile platform **1508** may include, for example, without limitation, electricity, air, water, hydraulic fluid, communications, some other type of utility, or some combination thereof.

[0319] With reference now to **Figure 16,** an illustration of an isometric cutaway view of a plurality of mobile platforms performing fastening processes within interior **1201** of fuselage assembly **1100** is depicted in accordance with an illustrative embodiment. In this illustrative example, plurality of mobile platforms **1600** may be used to perform fastening processes to join plurality of panels **1408** together.

[0320] In particular, plurality of panels **1408** may be joined together at selected locations along fuselage assembly **1100.** Plurality of panels **1408** may be joined to form at least one of lap joints, butt joints, or other types of joints. In this manner, plurality of panels **1408** may be joined such that at least one of circumferential attachment, longitudinal attachment, or some other type of attachment is created between the various panels of plurality of panels **1408.**

[0321] As depicted, plurality of mobile platforms **1600** may include internal mobile platform **1508** and internal mobile platform **1601.** Internal mobile platform **1508** and internal mobile platform **1601** may be an example of one implementation for number of internal mobile platforms **402** in **Figure 4.** Internal mobile platform **1508** may be configured to move along passenger floor **1300,** while internal mobile platform **1601** may be configured to move along cargo floor **1200.**

[0322] As depicted, internal robotic device **1602** and internal robotic device **1604** may be associated with internal mobile platform **1601.** Each of internal robotic device **1602** and internal robotic device **1604** may be an example of one implementation for internal robotic device **416** in **Figure 4.** Internal robotic device **1602** and internal robotic device **1604** may be similar to internal robotic device **1510** and internal robotic device **1512.**

[0323] Plurality of mobile platforms **1600** may also include external mobile platform **1605** and external mobile platform **1607.** External mobile platform **1605** and external mobile platform **1607** may be an example of one implementation for at least a portion of number of external mobile platforms **400** in **Figure 4.** External mobile platform **1605** and external mobile platform **1607** may be examples of implementations for external mobile platform **404** in **Figure 4.**

[0324] External robotic device **1606** may be associated with external mobile platform **1605.** External robotic device **1608** may be associated with external mobile platform **1607.** Each of external robotic device **1606** and external robotic device **1608** may be an example of one implementation for external robotic device **408** in **Figure 4.**

[0325] As depicted, external robotic device **1606** and internal robotic device **1512** may work collaboratively to install fasteners autonomously in fuselage assembly **1100.** These fasteners may take the form of, for example, without limitation, at least one of rivets, interference-fit bolts, non-interference-fit bolts, or other types of fasteners or fastener systems. Similarly, external robotic device **1608** and internal robotic device **1604** may work collaboratively to install fasteners autonomously in fuselage assembly **1100.** As one illustrative example, end effector **1610** of internal robotic device **1512** and end effector **1612** of external robotic device **1606** may be positioned relative to a same location **1620** on fuselage assembly **1100** to perform a fastening process at location **1620,** such as fastening process **424** in **Figure 4.**

[0326] The fastening process may include at least one of, for example, without limitation, a drilling operation, a fastener insertion operation, a fastener installation operation, an inspection operation, or some other type of operation. The fastener installation operation may take the form of, for example, without limitation, two-stage riveting process **444** described in **Figure 4,** interference-fit bolt-type installation process **439** described in **Figure 4,** bolt-nut type installation process **433** described in **Figure 4,** or some other type of fastener installation operation.

[0327] In this illustrative example, autonomous vehicle **1611** may be fixedly associated with external mobile platform **1605.** Autonomous vehicle **1611** may be used to drive external mobile platform **1605** autonomously. For example, autonomous vehicle **1611** may be used to autonomously drive external mobile platform **1605** across floor **703** of manufacturing environment **700** relative to assembly fixture **1012.**

[0328] Similarly, autonomous vehicle **1613** may be fixedly associated with external mobile platform **1607.** Autonomous vehicle **1613** may be used to drive external mobile platform **1607** autonomously. For example, autonomous vehicle **1613** may be used to autonomously drive external mobile platform **1607** across floor **703** of manufacturing environment **700** relative to assembly fixture **1012.**

[0329] By being fixedly associated with external mobile platform **1605** and external mobile platform **1607,** autonomous vehicle **1611** and autonomous vehicle **1613** may be considered integral to external mobile platform **1605** and external mobile platform **1607,** respectively. However, in other illustrative examples, these autonomous vehicles may be independent of the external mobile platforms in other illustrative examples.

[0330] Once all fastening processes have been completed for fuselage assembly **1100,** internal mobile platform **1508** and internal mobile platform **1601** may be autonomously driven across passenger floor **1300** back onto top platform **1506** and bottom platform **1507,** respectively, of second tower **1500.** Second tower **1500** may then be autonomously decoupled from both utility fixture **726** and assembly fixture **1012.** Autonomous vehicle **1614** may then be used to autonomously drive or move second tower **1500** away.

[0331] In this illustrative example, building of fuselage assembly **1100** may now be considered completed for this stage in the overall assembly process for the fuselage. Consequently, assembly fixture **1012** may be autonomously driven across floor **703** to move fuselage assembly **1100** to some other location. In other illustrative examples, first tower **800** from **Figure 8** may be autonomously driven back into selected tower position **818** in **Figure 8** relative to utility fixture **726.** First tower **800** from **Figure 8** may then be autonomously recoupled to utility fixture **726** and assembly fixture **1012.** First tower **800**

from **Figure 8** may enable a human operator (not shown) to access interior **1201** of fuselage assembly **1100** to perform other operations including, but not limited to, at least one of inspection operations, fastening operations, system installation operations, or other types of operations. System installation operations may include operations for installing systems such as, for example, without limitation, at least one of a fuselage utility system, an air conditioning system, interior panels, electronic circuitry, some other type of system, or some combination thereof.

[0332] With reference now to **Figure 17,** an illustration of a cross-sectional view of flexible manufacturing system **708** performing operations on fuselage assembly **1100** from **Figure 16** is depicted in accordance with an illustrative embodiment. In this illustrative example, a cross-sectional view of fuselage assembly **1100** from **Figure 16** is depicted taken in the direction of lines **17-17** in **Figure 16.**

[0333] As depicted, internal mobile platform **1508** and internal mobile platform **1601** are performing operations within interior **1201** of fuselage assembly **1100.** External mobile platform **1605** and external mobile platform **1607** are performing assembly operations along exterior **1700** of fuselage assembly **1100.**

[0334] In this illustrative example, external mobile platform **1605** may be used to perform operations along portion **1702** of exterior **1700** between axis **1704** and axis **1706** at first side **1710** of fuselage assembly **1100.** External robotic device **1606** of external mobile platform **1605** may work collaboratively with internal robotic device **1510** of internal mobile platform **1508** to perform fastening processes.

[0335] Similarly, external mobile platform **1607** may be used to perform operations along portion **1708** of exterior **1700** of fuselage assembly **1100** between axis **1704** and axis **1706** at second side **1712** of fuselage assembly **1100.** External robotic device **1608** of external mobile platform **1607** may work collaboratively with internal robotic device **1604** of internal mobile platform **1601** to perform fastening processes.

[0336] Although external mobile platform **1605** is depicted as being located at first side **1710** of fuselage assembly **1100,** external mobile platform **1605** may be autonomously driven by autonomous vehicle **1611** to second side **1712** of fuselage assembly **1100** to perform operations along portion **1711** of exterior **1700** of fuselage assembly **1100** between axis **1704** and axis **1706.** Similarly, external mobile platform **1607** may be autonomously driven by autonomous vehicle **1613** to second side **1712** of fuselage assembly **1100** to perform operations along portion **1713** of exterior **1700** of fuselage assembly **1100** between axis **1704** and axis **1706.**

[0337] Although not shown in this illustrative example, an external mobile platform similar to external mobile platform **1605** may have an external robotic device configured to work collaboratively with internal robotic device **1512** of internal mobile platform **1508** at second side **1712** of fuselage assembly **1100.** Similarly, an external mobile platform similar to external mobile platform **1607** may have an external robotic device configured to work collaboratively with internal robotic device **1602** of internal mobile platform **1601** at first side **1710** of fuselage assembly **1100.**

[0338] These four different external mobile platforms and two internal mobile platforms may be controlled such that the operations performed by internal mobile platform **1508** located on passenger floor **1300** may occur at a different location with respect to the longitudinal axis of fuselage assembly **1100** than the operations performed by internal mobile platform **1601** located on cargo floor **1200.** The four external mobile platforms may be controlled such that the two external mobile platforms located on the same side of fuselage assembly **1100** do not collide or impede one another. The two external mobile platforms located at the same side of fuselage assembly **1100** may be unable to occupy the same footprint in this illustrative example.

[0339] In this illustrative example, external mobile platform **1605** may autonomously couple to assembly fixture **1012** to form interface **1722** such that a number of utilities may flow from assembly fixture **1012** to external mobile platform **1605.** In other words, the number of utilities may be autonomously coupled between external mobile platform **1605** and assembly fixture **1012** through interface **1722.** In particular, external mobile platform **1605** has been coupled to cradle fixture **910** through interface **1722.**

[0340] Similarly, external mobile platform **1607** may autonomously couple to assembly fixture **1012** to form interface **1724** such that a number of utilities may flow from assembly fixture **1012** to external mobile platform **1607.** In other words, the number of utilities may be autonomously coupled between external mobile platform **1607** and assembly fixture **1012** through interface **1724.** In particular, external mobile platform **1607** has been coupled to cradle fixture **910** through interface **1724.**

[0341] As operations are performed along fuselage assembly **1100** by external mobile platform **1605,** external mobile platform **1607,** and any other external mobile platforms, these external mobile platforms may be coupled to and decoupled from assembly fixture **1012** as needed. For example, external mobile platform **1607** may decouple from cradle fixture **910** as external mobile platform **1607** moves aftward along fuselage assembly **1100** such that external mobile platform **1607** may then autonomously couple to cradle fixture **908** (not shown) from **Figures 9-16.** Further, these external mobile platforms may be coupled to and decoupled from assembly fixture **1012** to avoid collisions and prevent the external mobile platforms from impeding each other during maneuvering of the external mobile platforms relative to assembly fixture **1012** and fuselage assembly **1100.**

[0342] As depicted, autonomous vehicle **1714** is shown positioned under the assembly fixture **1012** formed by cradle system **900.** In this illustrative example, autonomous vehicle **1714,** autonomous vehicle **1611,**

and autonomous vehicle **1613** may have omnidirectional wheels **1716,** omnidirectional wheels **1718,** and omnidirectional wheels **1720,** respectively. In some illustrative examples, metrology system **1726** may be used to help position external mobile platform **1605** and external mobile platform **1607** relative to fuselage assembly **1100.**

[0343] Turning now to **Figure 18,** an illustration of an isometric view of a fully built fuselage assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, fuselage assembly **1100** may be considered completed when plurality of panels **1408** have been fully joined.

[0344] In other words, all fasteners needed to join together plurality of panels **1408** have been fully installed. With plurality of panels **1408** joined together, support structure **1800** may be fully formed. Support structure **1800** may be an example of one implementation for support structure **121** in **Figure 1.** Fuselage assembly **1100,** which is an aft fuselage assembly, may now be ready for attachment to a corresponding middle fuselage assembly (not shown) and forward fuselage assembly (not shown).

[0345] As depicted, autonomous vehicles (not shown in this view), similar to autonomous vehicle **1614** shown in **Figure 16,** may be positioned under base **912** of cradle fixture **906,** base **914** of cradle fixture **908,** and base **916** of cradle fixture **910,** respectively. Autonomous vehicles, such as number of corresponding autonomous vehicles **316** in **Figure 3,** may lift up base **912,** base **914,** and base **916,** respectively, such that plurality of stabilizing members **924,** plurality of stabilizing members **926,** and plurality of stabilizing members **928,** respectively, no longer contact the floor.

[0346] These autonomous vehicles (not shown) may then autonomously drive cradle system **900** carrying fuselage assembly **1100** that has been fully built away from assembly environment **702** in **Figure 7** and, in some cases, away from manufacturing environment **700** in **Figure 7.** Computer-controlled movement of these autonomous vehicles (not shown) may ensure that number of cradle fixtures **902** maintain their positions relative to each other as fuselage assembly **1100** is being moved.

[0347] With reference now to **Figure 19,** an illustration of an isometric view of fuselage assemblies being built within manufacturing environment **700** is depicted in accordance with an illustrative embodiment. In this illustrative example, plurality of fuselage assemblies **1900** are being built within plurality of work cells **712** in manufacturing environment **700.**

[0348] Plurality of fuselage assemblies **1900** may include plurality of forward fuselage assemblies **1901** being built in first portion **714** of plurality of work cells **712** and plurality of aft fuselage assemblies **1902** being built in second portion **716** of plurality of work cells **712.** Each of plurality of fuselage assemblies **1900** may be an example of one implementation for fuselage assembly **114** in **Figure 1.**

[0349] As depicted, plurality of fuselage assemblies **1900** are being built concurrently. However, plurality of fuselage assemblies **1900** are at different stages of assembly in this illustrative example.

[0350] Forward fuselage assembly **1904** may be an example of one of plurality of forward fuselage assemblies **1901.** Forward fuselage assembly **1904** may be an example of one implementation for forward fuselage assembly **117** in **Figure 1.** Aft fuselage assembly **1905** may be an example of one of plurality of aft fuselage assemblies **1902.** Aft fuselage assembly **1905** may be an example of one implementation for aft fuselage assembly **116** in **Figure 1.** In this illustrative example, aft fuselage assembly **1905** may be at an earlier stage of assembly than forward fuselage assembly **1904.**

[0351] Aft fuselage assembly **1906,** which may be another example of an implementation for aft fuselage assembly **116** in **Figure 1,** may be a fuselage assembly with all panels joined. As depicted, aft fuselage assembly **1906** is being autonomously driven to some other location for a next stage in the overall fuselage and aircraft manufacturing process.

[0352] As described above, aft fuselage assembly **1905** may be partially assembled. In this illustrative example, aft fuselage assembly **1905** has keel **1910,** end panel **1911,** and first side **1912.** End panel **1911** may form an end fuselage section of aft fuselage assembly **1905.** As depicted, side panel **1914** may be added to aft fuselage assembly **1905** to build a second side of aft fuselage assembly **1905.**

[0353] Forward fuselage assembly **1915** may be another example of one of plurality of forward fuselage assemblies **1901.** In this illustrative example, forward fuselage assembly **1915** has keel **1916** and end panel **1918.** End panel **1918** may form an end fuselage section of forward fuselage assembly **1915.** As depicted, side panel **1920** may be added to forward fuselage assembly **1915** to begin building a first side of forward fuselage assembly **1915.**

[0354] With reference now to **Figure 20,** an illustration of a top isometric view of internal mobile platform **1508** from **Figures 15-16** is depicted in accordance with an illustrative embodiment. In this illustrative example, one portion of internal mobile platform **1508** may include first section **2000** of platform base **2001.** Another portion of internal mobile platform **1508** may include second section **2002** of platform base **2001.** Platform base **2001** may be an example of one implementation for platform base **600** in **Figure 6.**

[0355] As depicted, set of units **2003** may be associated with internal mobile platform **1508.** Set of units **2003** may be an example of one implementation for set of units **662** in **Figure 6.** A number of utilities may be distributed to set of units **2003** through a number of utility cables (not shown in this view) in cable management system **1514** associated with second tower **1500** shown in **Figure 15.**

[0356] In this illustrative example, internal robotic device **1510** may be associated with first section **2000** of platform base **2001** of internal mobile platform **1508.** Internal robotic device **1512** may be associated with second section **2002** of platform base **2001** of internal mobile platform **1508.** As depicted, internal robotic device **1510** may be in initial position **2013** and internal robotic device **1512** may be in initial position **2011.**

[0357] In this illustrative example, robotic controller **2004** and robotic controller **2006** may be associated with platform base **2001** and used to control the operation and movement of internal robotic device **1510** and internal robotic device **1512,** respectively. As depicted, internal robotic device **1510** and internal robotic device **1512** may be associated with movement system **2008** and movement system **2010.** Movement system **2008** and movement system **2010** may be used to move internal robotic device **1510** and internal robotic device **1512,** respectively, in the direction of arrow **2014** about Z-axis **2016** relative to robotic base **2012** and robotic base **2018,** respectively.

[0358] In this illustrative example, internal robotic device **1510** and internal robotic device **1512** may take the form of robotic arm **2020** and robotic arm **2022,** respectively. As depicted, end effector **2024** may be associated with robotic arm **2020.** End effector **2026** may be associated with robotic arm **2022.**

[0359] Track system **2028** may be associated with platform base **2001.** Track system **2028** may be an example of one implementation for track system **640** in **Figure 6.** Track system **2028** may include track **2030** and track **2031.** Track **2030** and track **2031** may be used to drive internal mobile platform **1508** in the direction of X-axis **2032.**

[0360] With reference now to **Figure 21,** an illustration of a bottom isometric view of internal mobile platform **1508** from **Figure 20** is depicted in accordance with an illustrative embodiment. A bottom isometric view of internal mobile platform **1508** may be depicted taken in the direction of lines **21-21** in **Figure 20.**

[0361] In this illustrative example, track **2031** may include plurality of track pads **2100** and track **2030** may include plurality of track pads **2102.** Plurality of track pads **2100** and plurality of track pads **2102** may contact the surface along which internal mobile platform **1508** may be moved. In this illustrative example, plurality of track pads **2100** and plurality of track pads **2102** may be comprised of an elastomeric material, such as rubber. In other illustrative examples, these track pads may be comprised of some other type of material or combination of materials selected to reduce or prevent undesired effects on the floor on which internal mobile platform **1508** is moving.

[0362] With reference now to **Figure 22,** an illustration of an enlarged view of track **2030** is depicted in accordance with an illustrative embodiment. This view of track **2030** is depicted taken in the direction of lines **22-22** in **Figure 20.** As depicted, track **2030** may include at least one track wheel **2200.** Further, track **2030** also includes roller chain **2202,** plurality of rollers **2204,** and plurality of support plates **2206.**

[0363] Plurality of rollers **2204** may be associated with roller chain **2202.** Plurality of rollers **2204** and roller chain **2202** may be configured to move around track wheel **2200,** another track wheel (not shown in this view), and plurality of support plates **2206.** Plurality of support plates **2206** may be used to distribute the load of internal mobile platform **1508** substantially evenly across a floor along which internal mobile platform **1508** moves, such as passenger floor **1300** in **Figure 13,** in a manner that reduces point-loading on passenger floor **1300.** In particular, plurality of rollers **2204** rolling along plurality of support plates **2206** may reduce point-loading.

[0364] Point-loading may be reduced because the load of internal mobile platform **1508** is distributed over the larger surface area of plurality of support plates **2206** before being substantially evenly distributed to plurality of track pads **2102.** The portion of load transferred to the floor by each of plurality of track pads **2102** may be significantly less than the load that would be transferred if internal mobile platform **1508** was driven using a wheel-based movement system.

[0365] Turning now to **Figure 23,** an illustration of a side view of internal mobile platform **1508** from **Figure 20** is depicted in accordance with an illustrative embodiment. A side view of internal mobile platform **1508** from **Figure 20** is shown taken in the direction of lines **23-23** in **Figure 20.**

[0366] As depicted, internal mobile platform **1508** may have total height **2300.** Total height **2300** may be selected such that internal mobile platform **1508** may be freely moved along passenger floor **1300** of interior **1201** of fuselage assembly **1100** as shown in **Figures 16** and **17.**

[0367] Internal mobile platform **1508** may have dimensions that allow internal mobile platform **1508** and all of the components onboard internal mobile platform **1508** to move freely within interior **1201** of fuselage assembly **1100.**

[0368] In particular, internal mobile platform **1508** may have dimensions that allow internal mobile platform **1508** to move through interior **1201** along passenger floor **1300** without contacting the inner edges of the support structure associated with fuselage assembly **1100.** However, internal robotic device **1510** and internal robotic device **1512** may be capable of positioning the corresponding tools associated with these robotic devices at all locations along interior **1201** of fuselage assembly **1100** at which operations are to be performed by internal mobile platform **1508.**

[0369] With reference now to **Figure 24,** an illustration of internal mobile platform **1601** from **Figure 16** is depicted in accordance with an illustrative embodiment. In this illustrative example, internal mobile platform **1601** is depicted. Internal mobile platform **1601** may be driven along cargo floor **1200** of fuselage assembly **1100** as shown in **Figure 16.**

[0370] Internal mobile platform **1601** may be implemented in a manner similar to internal mobile platform **1508** described above in **Figures 20-23.** However, internal mobile platform **1601** may have dimensions that allow internal mobile platform **1601** and all of the components onboard internal mobile platform **1601** to move freely within interior **1201** of fuselage assembly **1100** as shown in **Figures 16** and **17.** In particular, internal mobile platform **1601** may have dimensions that allow internal mobile platform **1601** to move through interior **1201** along cargo floor **1200** without contacting the inner edges of the support structure associated with fuselage assembly **1100.** However, internal robotic device **1604** and internal robotic device **1602** may be capable of positioning the corresponding tools associated with these robotic devices at all locations along interior **1201** of fuselage assembly **1100** at which operations are to be performed by internal mobile platform **1601.**

[0371] As depicted, internal mobile platform **1601** may include platform base **2402.** Robotic base **2408** and robotic base **2410** may be associated with platform base **2402.** Internal robotic device **1604** and internal robotic device **1602** may be associated with internal mobile platform **1601** through robotic base **2408** and robotic base **2410,** respectively.

[0372] Movement system **2412** and movement system **2414** may be used to move internal robotic device **1604** and internal robotic device **1602,** respectively. Robotic controller **2416** may control the operation of movement system **2412,** internal robotic device **1604,** or both. Robotic controller **2418** may control the operation of movement system **2414,** internal robotic device **1602,** or both. End effector **2413** and end effector **2415** may be associated with internal robotic device **1604** and internal robotic device **1602,** respectively.

[0373] In this illustrative example, set of units **2419** is associated with platform base **2402.** Set of units **2419** may be connected to a number of utility cables associated with cable management system **1516** in **Figure 15.** As depicted, platform movement system **2420** may be associated with platform base **2402.** Platform movement system **2420** may take the form of track system **2422.** As depicted, track system **2422** may include track **2424** and track **2426.** Track system **2422** may be used to move internal mobile platform **1601** in the direction of arrow **2428.**

[0374] With reference now to **Figure 25,** an illustration of a bottom isometric view of internal mobile platform **1601** from **Figure 24** is depicted in accordance with an illustrative embodiment. This view of internal mobile platform **1601** is depicted taken in the direction of lines **25-25** in **Figure 24.** As depicted, track system **2422** may be implemented in a manner similar to track system **2028** of internal mobile platform **1508** shown in **Figures 20-23.**

[0375] Track system **2422** may be used to distribute the load of internal mobile platform **1601** substantially evenly across a floor along which internal mobile platform **1601** moves in a manner that reduces point-loading on the floor. The floor may be cargo floor **1200** shown in **Figures 12** and **16.**

[0376] With reference now to **Figure 26,** an illustration of a side view of internal mobile platform **1601** from **Figure 24** is depicted in accordance with an illustrative embodiment. This view of internal mobile platform **1601** is depicted taken in the direction of lines **26-26** in **Figure 24.** As depicted, internal mobile platform **1601** may have total height **2600.**

[0377] Total height **2600** may be lower than total height **2300** of internal mobile platform **1508** in **Figure 23.** Internal mobile platform **1601** may be shorter than internal mobile platform **1508** because there may be reduced clearance between passenger floor **1300** and cargo floor **1200** of fuselage assembly **1100,** as shown in **Figure 16,** as compared to between passenger floor **1300** and the interior of crown **1407** of fuselage assembly **1100** in **Figure 15.** In other words, total height **2600** may be selected such that internal mobile platform **1601** may be freely moved along cargo floor **1200** within interior **1201** of fuselage assembly **1100** as shown in **Figures 15** and **16.**

[0378] With reference now to **Figure 27,** an illustration of internal mobile platform **1508** moving inside fuselage assembly **1100** is depicted in accordance with an illustrative embodiment. In this illustrative example, internal mobile platform **1508** has moved within interior **1201** of fuselage assembly **1100.** In particular, internal mobile platform **1508** has moved in the direction of arrow **2700** across passenger floor **1300.** Internal robotic device **1510** has new position **2702** and internal robotic device **1512** has new position **2704.**

[0379] As depicted, number of utility cables **2706** has been extended from cable management system **1514.** Cable management system **1514** may ensure that number of utility cables **2706** stay organized and untangled as internal mobile platform **1508** moves in the direction of arrow **2700.** A number of utilities may be distributed to internal mobile platform **1508** through number of utility cables **2706.**

[0380] The illustrations in **Figures 7-27** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional.

[0381] The different components shown in **Figures 7-27** may be illustrative examples of how components shown in block form in **Figures 1-6** can be implemented as physical structures. Additionally, some of the components in **Figures 7-27** may be combined with components in **Figures 1-6,** used with components in **Figures 1-6,** or a combination of the two.

[0382] Turning now to **Figure 28,** an illustration of a process for performing an assembly operation is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 28** may be implemented using flexible manufacturing system **106** in **Figure 1.** In particular, this process may be implemented using an internal mobile platform, such as internal mobile platform **406** in **Figure 4** to perform an assembly operation for an aircraft, such as aircraft **104** in **Figure 1.**

[0383] The process may begin by macro-positioning a tool within interior **236** of fuselage assembly **114** (operation **2800).** The tool may be micro-positioned relative to particular location **635** on panel **216** of fuselage assembly **114** (operation **2802).** Thereafter, assembly operation **637** may be performed at particular location **635** on panel **216** using tool **631** (operation **2804),** with the process terminating thereafter. In this illustrative example, assembly operation **637** may be performed in coordination with a corresponding assembly operation being performed at the particular location on exterior **234** of fuselage assembly **114.**

[0384] Turning now to **Figure 29,** an illustration of a process for performing an assembly operation is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 29** may be implemented using flexible manufacturing system **106** in **Figure 1.** In particular, this process may be implemented using an internal mobile platform, such as internal mobile platform **406** in **Figure 4** to perform an assembly operation for an aircraft, such as aircraft **104** in **Figure 1.**

[0385] The process may begin by driving tower **332** having internal mobile platform **406** located on a platform level of tower **332** relative to assembly fixture **324** supporting fuselage assembly **114** (operation **2900).** Next, tower **332** may be coupled to utility fixture **150** (operation **2902).** Number of utilities **146** may then be distributed to internal mobile platform **406** through cable management system **665** associated with tower **332** (operation **2904).**

[0386] Internal mobile platform **406** may be driven from tower **332** onto one of number of floors **266** of fuselage assembly **114** using track system **640** to macro-position an internal tool associated with internal mobile platform **406** relative to panel **216** of fuselage assembly **114** (operation **2906).** During operation **2906,** cable management system **665** may help manage number of utility cables **664** providing number of utilities **146** to internal mobile platform **406** as internal mobile platform **406** moves along the floor of fuselage assembly **114.**

[0387] The internal tool may then be micro-positioned relative to particular location **635** on panel **216** using internal robotic device **416** associated with internal mobile platform **406** (operation **2908).** Thereafter, assembly operation **637** may be performed within interior **236** of fuselage assembly **114** at particular location **635** on panel **216** using the internal tool in coordination with an external tool performing a corresponding assembly operation at particular location **635** on exterior **234** of fuselage assembly **114** (operation **2910),** with the process terminating thereafter.

[0388] With reference now to **Figure 30,** an illustration of a process for reducing point-loading by an internal mobile platform is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 30** may be implemented using track system **640** of internal mobile platform **406** in **Figure 6.**

[0389] The process may begin by moving internal mobile platform **406** along floor **300** of fuselage assembly **114** using track system **640** (operation **3000).** The floor may be, for example, first floor **623** or second floor **625** in **Figure 6.** Total load **651** of internal mobile platform **406** may be substantially evenly distributed using track system **640** as internal mobile platform **406** moves along the floor (operation **3002),** with the process terminating thereafter. In operation **3002,** the load may be distributed using plurality of support plates **654.** By distributing total load **651** of internal mobile platform **406** substantially evenly, track system **640** may reduce point-loading **655** by internal mobile platform **406** on the floor.

[0390] With reference now to **Figure 31,** an illustration of a process for performing fastening operations is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 31** may be performed using, for example, without limitation, internal mobile platform **406** shown in **Figures 4** and **6** to perform a fastening operation in fastening process **424.**

[0391] The process may begin by driving internal mobile platform **406** into position **633** relative to panel **216** of fuselage assembly **114** (operation **3100).** Next, a set of locations on panel **216** for performing a fastening operation may be identified (operation **3102).** Thereafter, a fastening operation may be performed at each of the set of locations identified using a tool associated with internal mobile platform **406** (operation **3104),** with the process terminating thereafter.

[0392] With reference now to **Figure 32,** an illustration of a process for performing fastening operations is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 32** may be performed using, for example, without limitation, internal mobile platform **406** shown in **Figures 4** and **6** to perform an operation in fastening process **424.**

[0393] The process may begin by driving internal mobile platform **406** into position **633** within interior **236** of fuselage assembly **114** relative to panel **216** of fuselage assembly **114** (operation **3200).** Next, a first location of a first temporary fastener installed in panel **216** may be identified with respect to a reference coordinate system using an imaging system (operation **3202).** The imaging system may then be moved in a translational direction until a second temporary fastener installed in the panel enters a field of view of the imaging system (operation **3204).** In other illustrative examples, detection of the second temporary fastener in operation **3204** may be performed by widening the field of view of the imaging system until the second fastener is detected. For example, the imaging system may be zoomed out from the first location of the first temporary fastener until the second temporary fastener is detected. A second location of the second temporary fastener may then be identified with respect to the reference coordinate system (operation **3206).**

[0394] Thereafter, a set of locations between the first location of the first temporary fastener and the second location of the second temporary fastener is identified (operation **3208).** A fastening operation may then be performed at each of the set of locations identified (operation **3210),** with the process terminating thereafter.

[0395] In one illustrative example, for each particular location in the set of locations, operation **3210** may be performed by performing a riveting operation at the particular location using a riveting tool. For example, the tool may be a bucking bar that is used in coordination with a hammer positioned at particular location **635** on panel **216** at exterior **234** of fuselage assembly **114.**

[0396] The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, a segment, a function, a portion of an operation or step, some combination thereof.

[0397] In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[0398] Turning now to **Figure 33,** an illustration of a data processing system is depicted in the form of a block diagram in accordance with an illustrative embodiment. Data processing system **3300** may be used to implement any of the controllers described above, including control system **136** in **Figure 1.** In some illustrative examples, data processing system **3300** may be used to implement at least one of a controller in set of controllers **140** in **Figure 1,** first robotic controller **616** in **Figure 6,** or second robotic controller **624** in **Figure 6.**

[0399] As depicted, data processing system **3300** includes communications framework **3302,** which provides communications between processor unit **3304,** storage devices **3306,** communications unit **3308,** input/output unit **3310,** and display **3312.** In some cases, communications framework **3302** may be implemented as a bus system.

[0400] Processor unit **3304** is configured to execute instructions for software to perform a number of operations. Processor unit **3304** may comprise at least one of a number of processors, a multi-processor core, or some other type of processor, depending on the implementation. In some cases, processor unit **3304** may take the form of a hardware unit, such as a circuit system, an application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware unit.

[0401] Instructions for the operating system, applications and programs run by processor unit **3304** may be located in storage devices **3306.** Storage devices **3306** may be in communication with processor unit **3304** through communications framework **3302.** As used herein, a storage device, also referred to as a computer readable storage device, is any piece of hardware capable of storing information on a temporary basis, a permanent basis, or both. This information may include, but is not limited to, data, program code, other information, or some combination thereof.

[0402] Memory **3314** and persistent storage **3316** are examples of storage devices **3306.** Memory **3314** may take the form of, for example, a random access memory or some type of volatile or non-volatile storage device. Persistent storage **3316** may comprise any number of components or devices. For example, persistent storage **3316** may comprise a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **3316** may or may not be removable.

[0403] Communications unit **3308** allows data processing system **3300** to communicate with other data processing systems, devices, or both. Communications unit **3308** may provide communications using physical communications links, wireless communications links, or both.

[0404] Input/output unit **3310** allows input to be received from and output to be sent to other devices connected to data processing system **3300.** For example, input/output unit **3310** may allow user input to be received through a keyboard, a mouse, some other type of input device, or a combination thereof. As another example, input/output unit **3310** may allow output to be sent to a printer connected to data processing system **3300.**

[0405] Display **3312** is configured to display information to a user. Display **3312** may comprise, for example, without limitation, a monitor, a touch screen, a laser display, a holographic display, a virtual display device, some other type of display device, or a combination thereof.

[0406] In this illustrative example, the processes of the different illustrative embodiments may be performed by processor unit **3304** using computer-implemented instructions. These instructions may be referred to as program code, computer usable program code, or computer readable program code and may be read and executed by one or more processors in processor unit **3304.**

[0407] In these examples, program code **3318** is located in a functional form on computer readable media **3320,** which is selectively removable, and may be loaded onto or transferred to data processing system **3300** for execution by processor unit **3304.** Program code **3318** and computer readable media **3320** together form computer program product **3322.** In this illustrative example, computer readable media **3320** may be computer readable storage media **3324** or computer readable signal media **3326.**

[0408] Computer readable storage media **3324** is a physical or tangible storage device used to store program code **3318** rather than a medium that propagates or transmits program code **3318.** Computer readable storage media **3324** may be, for example, without limitation, an optical or magnetic disk or a persistent storage device that is connected to data processing system **3300.**

[0409] Alternatively, program code **3318** may be transferred to data processing system **3300** using computer readable signal media **3326.** Computer readable signal media **3326** may be, for example, a propagated data signal containing program code **3318.** This data signal may be an electromagnetic signal, an optical signal, or some other type of signal that can be transmitted over physical communications links, wireless communications links, or both.

[0410] The illustration of data processing system **3300** in **Figure 33** is not meant to provide architectural limitations to the manner in which the illustrative embodiments may be implemented. The different illustrative embodiments may be implemented in a data processing system that includes components in addition to or in place of those illustrated for data processing system **3300.** Further, components shown in **Figure** 33 may be varied from the illustrative examples shown.

[0411] The illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **3400** as shown in **Figure 34** and aircraft **3500** as shown in **Figure 35.** Turning first to **Figure 34,** an illustration of an aircraft manufacturing and service method is depicted in the form of a block diagram in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **3400** may include specification and design **3402** of aircraft **3500** in **Figure 35** and material procurement **3404.**

[0412] During production, component and subassembly manufacturing **3406** and system integration **3408** of aircraft **3500** in **Figure 35** takes place. Thereafter, aircraft **3500** in **Figure 35** may go through certification and delivery **3410** in order to be placed in service **3412.** While in service **3412** by a customer, aircraft **3500** in **Figure 35** is scheduled for routine maintenance and service **3414,** which may include modification, reconfiguration, refurbishment, and other maintenance or service.

[0413] Each of the processes of aircraft manufacturing and service method **3400** may be performed or carried out by at least one of a system integrator, a third party, or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

[0414] With reference now to **Figure 35,** an illustration of an aircraft is depicted in the form of a block diagram in which an illustrative embodiment may be implemented. In this example, aircraft **3500** is produced by aircraft manufacturing and service method **3400** in **Figure 34** and may include airframe **3502** with plurality of systems **3504** and interior **3506.** Examples of systems **3504** include one or more of propulsion system **3508,** electrical system **3510,** hydraulic system **3512,** and environmental system **3514.** Any number of other systems may be included. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

[0415] Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **3400** in **Figure 34.** In particular, flexible manufacturing system **106** from **Figure** 1 may be used to build at least a portion of airframe **3502** of aircraft **3500** during any one of the stages of aircraft manufacturing and service method **3400.** For example, without limitation, flexible manufacturing system **106** from **Figure 1** may be used during at least one of component and subassembly manufacturing **3406,** system integration **3408,** or some other stage of aircraft manufacturing and service method **3400** to form a fuselage for aircraft **3500.**

[0416] In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **3406** in **Figure 34** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **3500** is in service **3412** in **Figure 34.** As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing **3406** and system integration **3408** in **Figure 34.** One or more apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **3500** is in service **3412,** during maintenance and service **3414** in **Figure 34,** or both. The use of a number of the different illustrative embodiments may substantially expedite the assembly of and reduce the cost of aircraft **3500.**

[0417] The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

Claims

1. A method for performing an assembly operation (637), the method comprising:

    macro-positioning (2800) a tool (630, 632) within an interior (1201) of a fuselage assembly (1100); micro-positioning (2802) the tool (630, 632) relative to a particular location (635) on a panel (1408) of the fuselage assembly (1100); and

performing (2804) the assembly operation (637) at the particular location (635) on the panel (1408) using the tool (630, 632),
wherein:

macro-positioning the tool (630, 632) comprises moving a platform base (600) of an internal mobile platform (1508) carrying the tool (630, 632) with at least one degree of freedom relative to a floor (703) inside the fuselage assembly (1100);
and wherein:

a track system (2028) including a first track (2030) and a second track (2031) is associated with the platform base (600), the first and second tracks (2030, 2031) being for driving the internal mobile platform (1508) in a first direction (2032); and
the first and second tracks (2030, 2031) include a roller chain (2202), a plurality of rollers (2204), and a plurality of support plates (2206).

2. The method of claim 1, wherein micro-positioning the tool (630, 632) comprises:
moving the tool (630, 632) with the at least one degree of freedom relative to the platform base (600).

3. The method of claim 1, wherein micro-positioning the tool (630, 632) comprises:
commanding at least one of an internal robotic device (1510, 612, 620) or a movement system (614, 622) associated with the internal mobile platform (1508) to move the tool (630, 632) with the at least one degree of freedom relative to the platform base (600) to the particular location (635).

4. The method of claim 1, wherein macro-positioning the tool (630, 632) comprises:
driving an internal mobile platform (1508) carrying the tool (630, 632) across a floor (703) within the interior (1201) of the fuselage assembly (1100).

5. The method of claim 1, wherein driving the internal mobile platform (1508) comprises:
driving the internal mobile platform (1508) carrying the tool (630, 632) across the floor (703) within the interior (1201) of the fuselage assembly (1100) to an internal position (422) relative to the panel (1408) of the fuselage assembly (1100).

6. The method of claim 1, wherein performing the assembly operation (637) comprises:
performing a riveting operation at the particular location (635) using the tool (630, 632).

7. The method of claim 1, wherein macro-positioning the tool (630, 632) comprises:
driving an internal mobile platform (1508) autonomously across a platform level (615, 617) of a tower (332) onto a floor (703) within the interior (1201) of the fuselage assembly (1100) and into a position (633) relative to the panel (1408).

8. The method of claim 7 further comprising:
receiving a number of utilities (146) at the internal mobile platform (1508) through a number of utility cables (2706) extending from a cable management system (1514) associated with the tower (332).

9. The method of claim 1 further comprising:
removably associating an end effector (2024) with an internal robotic device (1510, 612, 620) associated with an internal mobile platform (1508).

10. An apparatus comprising:

a macro-positioning system (611) associated with an internal mobile platform (1508); and
a micro-positioning system (613) associated with the internal mobile platform (1508),
wherein the micro-positioning system (613) comprises:
a movement system (614, 622) for moving a tool (630, 632) with at least one degree of freedom relative to a platform base (600) of the internal mobile platform (1508);
and wherein the macro-positioning system (611) comprises:

a platform movement system (638) for moving a platform base (600) of the internal mobile platform (1508) with at least one degree of freedom relative to a floor (703) inside a fuselage assembly (1100), wherein
a track system (2028) including a first track (2030) and a second track (2031) is associated with the platform base (600), the first and second tracks (2030, 2031) being for driving the internal mobile platform (1508) in a first direction (2032), the first and second tracks (2030, 2031) including a roller chain (2202), a plurality of rollers (2204), and a plurality of support plates (2206).

11. The apparatus of claim 10, wherein the micro-positioning system (613) comprises at least one of an internal robotic device (1510, 612, 620) associated with the internal mobile platform (1508) or a movement system (614, 622).

12. The apparatus of claim 10 further comprising: the internal mobile platform (1508).

13. The apparatus of claim 10, wherein the internal mobile platform (1508) comprises: a set of units (662) connected to a number of utility cables (2706) that extend from a cable management system (1514).

14. The apparatus of claim 10, wherein the internal mobile platform (1508) comprises:

a platform base (600); and
a number of robotic systems (602) associated with the platform base (600).

15. The apparatus of claim 14, wherein the number of robotic systems (602) comprises:

a first robotic system (606); and
a second robotic system (608).

Patentansprüche

1. Verfahren zum Durchführen eines Montagevorgangs (637), wobei das Verfahren umfasst:

Makropositionieren (2800) eines Werkzeugs (630, 632) innerhalb eines Innenraums (1201) einer Rumpfbaugruppe (1100);
Mikropositionieren (2802) des Werkzeugs (630, 632) relativ zu einer bestimmten Stelle (635) auf einer Platte (1408) der Rumpfbaugruppe (1100); und
Durchführen (2804) des Montagevorgangs (637) an der bestimmten Stelle (635) auf der Platte (1408) unter Verwendung des Werkzeugs (630, 632),
wobei:
das Makropositionieren des Werkzeugs (630, 632) das Bewegen einer Plattformbasis (600) einer das Werkzeug (630, 632) tragenden internen mobilen Plattform (1508) mit mindestens einem Freiheitsgrad relativ zu einem Boden (703) innerhalb der Rumpfbaugruppe (1100) umfasst; und wobei:

ein Schienensystem (2028) mit einer ersten Schiene (2030) und einer zweiten Schiene (2031) der Plattformbasis (600) zugeordnet ist, wobei die erste und die zweite Schiene (2030, 2031) zum Fahren der internen mobilen Plattform (1508) in einer ersten Richtung (2032) dienen; und
die erste und zweite Schiene (2030, 2031) eine Rollenkette (2202), eine Mehrzahl von Rollen (2204) und eine Mehrzahl von Stützplatten (2206) umfassen.

2. Verfahren nach Anspruch 1, bei dem das Mikropositionieren des Werkzeugs (630, 632) umfasst: Bewegen des Werkzeugs (630, 632) mit dem mindestens einen Freiheitsgrad relativ zu der Plattformbasis (600).

3. Verfahren nach Anspruch 1, bei dem das Mikropositionieren des Werkzeugs (630, 632) umfasst: Anweisen mindestens einer internen Robotervorrichtung (1510, 612, 620) oder eines der internen mobilen Plattform (1508) zugeordneten Bewegungssystems (614, 622), das Werkzeug (630, 632) mit dem mindestens einen Freiheitsgrad relativ zur Plattformbasis (600) zu der bestimmten Stelle (635) zu bewegen.

4. Verfahren nach Anspruch 1, bei dem das Makropositionieren des Werkzeugs (630, 632) umfasst: Fahren einer das Werkzeug (630, 632) tragenden internen mobilen Plattform (1508) über einen Boden (703) innerhalb des Innenraums (1201) der Rumpfbaugruppe (1100).

5. Verfahren nach Anspruch 1, wobei das Antreiben der internen mobilen Plattform (1508) umfasst: Fahren der das Werkzeug (630, 632) tragenden internen mobilen Plattform (1508) über den Boden (703) innerhalb des Innenraums (1201) der Rumpfbaugruppe (1100) zu einer internen Position (422) relativ zu der Platte (1408) der Rumpfbaugruppe (1100).

6. Verfahren nach Anspruch 1, wobei das Durchführen des Montagevorgangs (637) umfasst: Durchführen eines Nietvorgangs an der bestimmten Stelle (635) unter Verwendung des Werkzeugs (630, 632).

7. Verfahren nach Anspruch 1, wobei das Makropositionieren des Werkzeugs (630, 632) umfasst: autonomes Fahren einer internen mobilen Plattform (1508) über eine Plattformebene (615, 617) eines Turms (332) auf einen Boden (703) innerhalb des Innenraums (1201) der Rumpfbaugruppe (1100) und in eine Position (633) relativ zu der Platte (1408).

8. Verfahren nach Anspruch 7, das ferner umfasst: Empfangen einer Anzahl von Betriebsmitteln (146) an der internen mobilen Plattform (1508) über eine Anzahl von Versorgungskabeln (2706), die von einem dem Turm (332) zugeordneten Kabelmanagementsystem (1514) ausgehen.

9. Verfahren nach Anspruch 1, das ferner umfasst: lösbares Zuordnen eines Endeffektors (2024) zu einer einer internen mobilen Plattform (1508) zugeordneten Robotervorrichtung (1510, 612, 620).

10. Vorrichtung umfassend:

ein Makropositioniersystem (611), das einer internen mobilen Plattform (1508) zugeordnet ist; und
ein Mikropositioniersystem (613), das der internen mobilen Plattform (1508) zugeordnet ist, wobei das Mikropositioniersystem (613) umfasst:
ein Bewegungssystem (614, 622) zum Bewegen eines Werkzeugs (630, 632) mit mindestens einem Freiheitsgrad relativ zu einer Plattformbasis (600) der internen mobilen Plattform (1508);
und wobei das Makropositioniersystem (611) umfasst:

ein Plattformbewegungssystem (638) zum Bewegen einer Plattformbasis (600) der internen mobilen Plattform (1508) mit mindestens einem Freiheitsgrad relativ zu einem Boden (703) innerhalb einer Rumpfbaugruppe (1100), wobei
der Plattformbasis (600) ein Schienensystem (2028) zugeordnet ist, das eine erste Schiene (2030) und eine zweite Schiene (2031) umfasst, wobei die erste und die zweite Schiene (2030, 2031) zum Fahren der internen mobilen Plattform (1508) in einer ersten Richtung (2032) dienen,
wobei die erste und die zweite Schiene (2030, 2031) eine Rollenkette (2202), eine Mehrzahl von Rollen (2204) und eine Mehrzahl von Stützplatten (2206) umfassen.

11. Vorrichtung nach Anspruch 10, bei der das Mikropositioniersystem (613) eine interne Robotervorrichtung (1510, 612, 620), die der internen mobilen Plattform (1508) zugeordnet ist, und/oder ein Bewegungssystem (614, 622) umfasst.

12. Vorrichtung nach Anspruch 10, die ferner die interne mobile Plattform (1508) umfasst.

13. Vorrichtung nach Anspruch 10, wobei die interne mobile Plattform (1508) umfasst:
einen Satz von Einheiten (662), die mit einer Anzahl von Versorgungskabeln (2706) verbunden sind, die von einem Kabelmanagementsystem (1514) ausgehen.

14. Vorrichtung nach Anspruch 10, bei der die interne mobile Plattform (1508) umfasst:

eine Plattformbasis (600); und
eine Anzahl von der Plattformbasis (600) zugeordneten Robotersystemen (602).

15. Vorrichtung nach Anspruch 14, bei der die Anzahl von Robotersystemen (602) umfasst:

ein erstes Robotersystem (606); und
ein zweites Robotersystem (608).

Revendications

1. Procédé de réalisation d'une opération d'assemblage (637), ce procédé comprenant :

le macro-positionnement (2800) d'un outil (630, 632) dans un intérieur (1201) d'un assemblage de fuselage (1100) ;
le micro-positionnement (2802) de l'outil (630, 632) par rapport à un emplacement particulier (635) sur un panneau (1408) de l'assemblage de fuselage (1100) ; et
la réalisation (2804) de l'opération d'assemblage (637) au niveau de l'emplacement particulier (635) sur le panneau (1408) à l'aide de l'outil (630, 632),
dans lequel :
le macro-positionnement de l'outil (630, 632) comprend le déplacement d'une base de plateforme (600) d'une plate-forme mobile interne (1508) supportant l'outil (630, 632) avec au moins un degré de liberté par rapport à un plancher (703) à l'intérieur de l'assemblage de fuselage (1100) ;
et dans lequel :

un système de piste (2028) comprenant une première piste (2030) et une deuxième piste (2031) est associé avec la base de plateforme (600), les première et deuxième pistes (2030, 2031) étant conçues pour entraîner la plate-forme mobile interne (1508) dans une première direction (2032) ; et
les première et deuxième pistes (2030, 2031) comprennent une chaîne à rouleaux (2202), une pluralité de rouleaux (2204) et une pluralité de plaques de support (2206).

2. Procédé selon la revendication 1, dans lequel le micro-positionnement de l'outil (630, 632) comprend : le déplacement de l'outil (630, 632) avec l'au moins un degré de liberté par rapport à la base de plateforme (600).

3. Procédé selon la revendication 1, dans lequel le micro-positionnement de l'outil (630, 632) comprend : la commande d'au moins un dispositif robotique interne (1510, 612, 620) ou d'un système de déplacement (614, 622) associé avec la plate-forme mobile interne (1508) afin de déplacer l'outil (630, 632) avec l'au moins un degré de liberté par rapport à la base de plate-forme (600) vers l'emplacement particulier (635).

4. Procédé selon la revendication 1, dans lequel le macro-positionnement de l'outil (630, 632) comprend :
l'entraînement d'une plate-forme mobile interne (1508) supportant l'outil (630, 632) à travers un plancher (703) dans l'intérieur (1201) de l'assemblage de fuselage (1100).

5. Procédé selon la revendication 1, dans lequel l'entraînement de la plate-forme mobile interne (1508) comprend :
l'entraînement de la plate-forme mobile interne (1508) supportant l'outil (630, 632) à travers le plancher (703) dans l'intérieur (1201) de l'assemblage de fuselage (1100) vers une position interne (422) par rapport au panneau (1408) de l'assemblage de fuselage (1100).

6. Procédé selon la revendication 1, dans lequel la réalisation de l'opération d'assemblage (637) comprend :
la réalisation d'une opération de rivetage au niveau de l'emplacement particulier (635) à l'aide de l'outil (630, 632) .

7. Procédé selon la revendication 1, dans lequel le macro-positionnement de l'outil (630, 632) comprend :
l'entraînement d'une plate-forme mobile interne (1508) de manière autonome à travers un niveau de plate-forme (615, 617) d'une tour (332) vers un plancher (703) dans l'intérieur (1201) de l'assemblage de fuselage (1100) et vers une position (633) par rapport au panneau (1408).

8. Procédé selon la revendication 7, comprenant en outre :
la réception d'un nombre de services (146) au niveau de la plate-forme mobile interne (1508) grâce à un nombre de câbles de services (2706) s'étendant à partir d'un système de gestion de câbles (1514) associé avec la tour (332).

9. Procédé selon la revendication 1, comprenant en outre :
l'association amovible d'un effecteur d'extrémité (2024) avec un dispositif robotique interne (1510, 612, 620) associé avec une plate-forme mobile interne (1508).

10. Appareil comprenant :

un système de macro-positionnement (611) associé avec une plate-forme mobile interne (1508) ; et
un système de micro-positionnement (613) associé avec la plate-forme mobile interne (1508), dans lequel le système de micro-positionnement (613) comprend :
un système de déplacement (614, 622) pour le déplacement d'un outil (630, 632) avec au moins un degré de liberté par rapport à une base de plate-forme (600) de la plate-forme mobile interne (1508) ;
et dans lequel le système de macro-positionnement (611) comprend :

un système de déplacement de plate-forme (638) pour le déplacement d'une base de plate-forme (600) de la plate-forme mobile interne (1508) avec au moins un degré de liberté par rapport à un plancher (703) à l'intérieur d'un assemblage de fuselage (1100), dans lequel
un système de piste (2028) comprenant une première piste (2030) et une deuxième piste (2031) est associé avec la base de plate-forme (600), les première et deuxième pistes (2030, 2031) étant conçues pour entraîner la plate-forme mobile interne (1508) dans une première direction (2032) ; et
les première et deuxième pistes (2030, 2031) comprennent une chaîne à rouleaux (2202), une pluralité de rouleaux (2204) et une pluralité de plaques de support (2206).

11. Appareil selon la revendication 10, dans lequel le système de micro-positionnement (613) comprend au moins un élément parmi un dispositif robotique interne (1510, 612, 620) associé avec la plate-forme mobile interne (1508) ou un système de déplacement (614, 622).

12. Appareil selon la revendication 10, comprenant en outre :
la plate-forme mobile interne (1508).

13. Appareil selon la revendication 10, dans lequel la plate-forme mobile interne (1508) comprend :
un ensemble d'unités (662) connectées à un nombre de câbles de services (2706) qui s'étendent à partir d'un système de gestion de câbles (1514).

14. Appareil selon la revendication 10, dans lequel la plate-forme mobile interne (1508) comprend :

une base de plate-forme (600) ; et
un nombre de systèmes robotiques (602) associés avec la base de plate-forme (600).

15. Appareil selon la revendication 14, dans lequel le nombre de systèmes robotiques (602) comprend :

un premier système robotique (606) ; et
un deuxième système robotique (608).

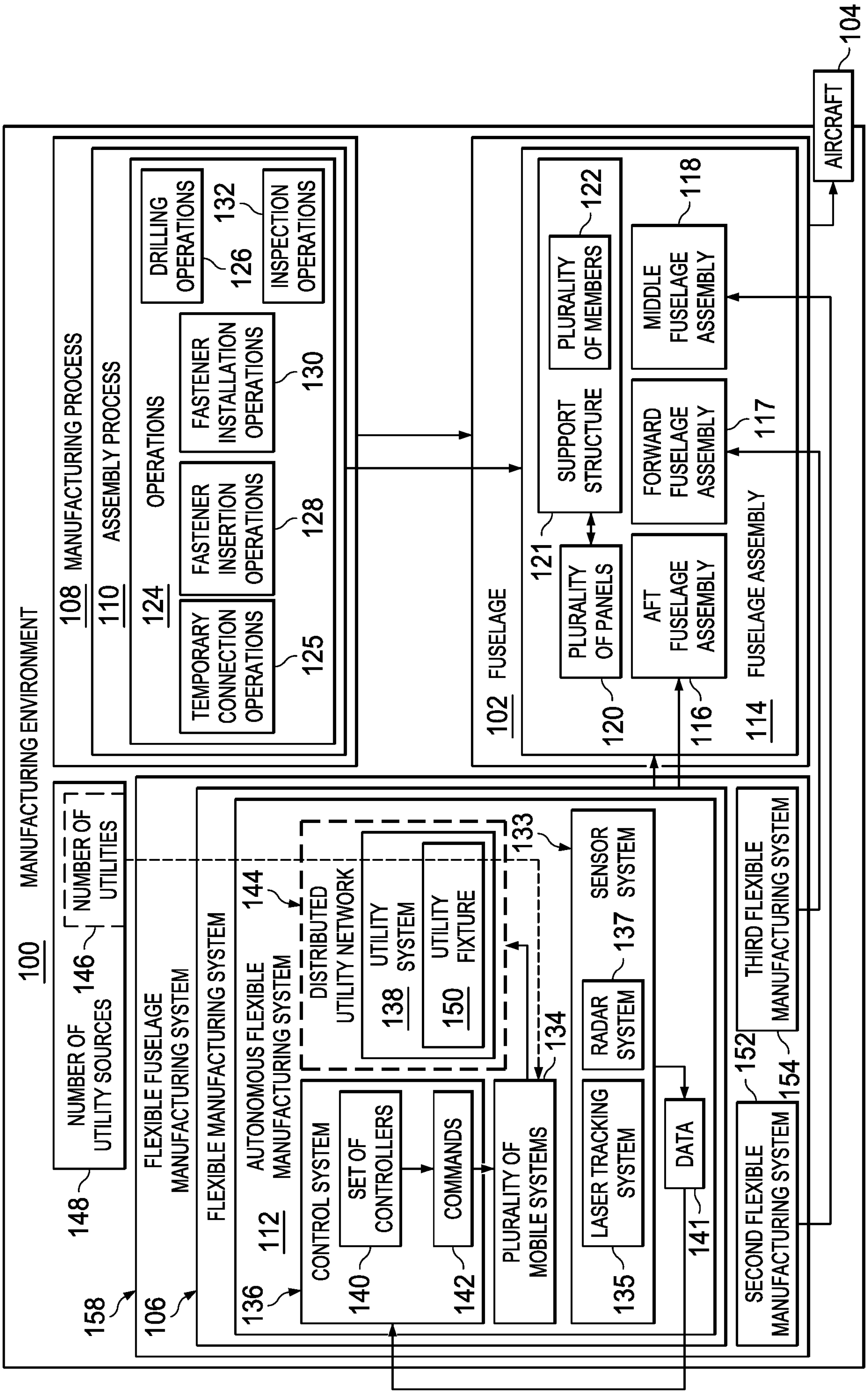
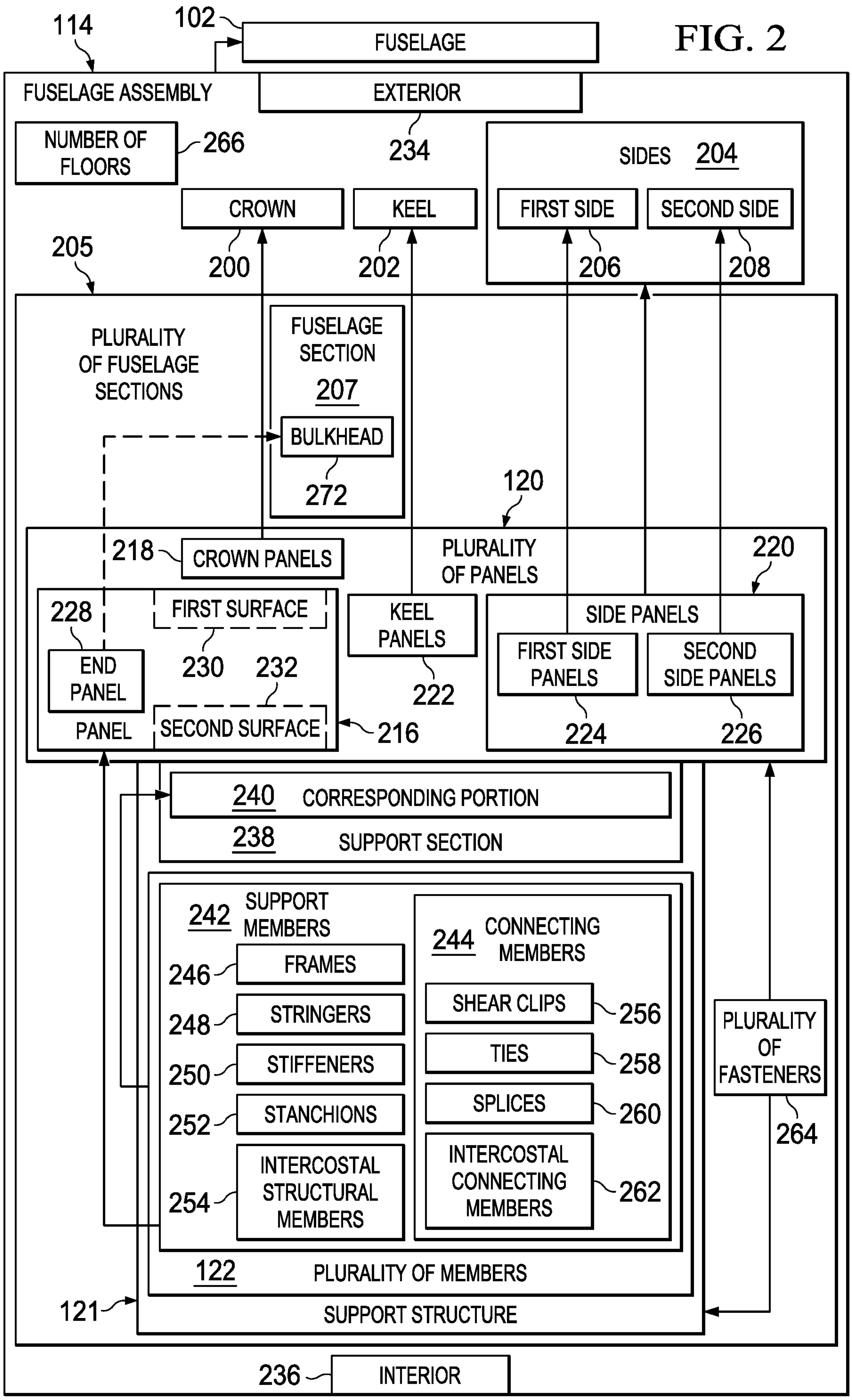

100 MANUFACTURING ENVIRONMENT
108 MANUFACTURING PROCESS
110 ASSEMBLY PROCESS
124 OPERATIONS
TEMPORARY CONNECTION OPERATIONS
125
FASTENER INSERTION OPERATIONS
128
FASTENER INSTALLATION OPERATIONS
130
DRILLING OPERATIONS
126
INSPECTION OPERATIONS
132
102 FUSELAGE
PLURALITY OF PANELS
120
121
SUPPORT STRUCTURE
PLURALITY OF MEMBERS
122
AFT FUSELAGE ASSEMBLY
116
FORWARD FUSELAGE ASSEMBLY
117
MIDDLE FUSELAGE ASSEMBLY
118
114 FUSELAGE ASSEMBLY
AIRCRAFT
104
148
NUMBER OF UTILITY SOURCES
146
NUMBER OF UTILITIES
158
FLEXIBLE FUSELAGE MANUFACTURING SYSTEM
106
FLEXIBLE MANUFACTURING SYSTEM
136
112 AUTONOMOUS FLEXIBLE MANUFACTURING SYSTEM
144
DISTRIBUTED UTILITY NETWORK
138 UTILITY SYSTEM
150 UTILITY FIXTURE
CONTROL SYSTEM
140
SET OF CONTROLLERS
142
COMMANDS
PLURALITY OF MOBILE SYSTEMS
134
133
SENSOR SYSTEM
137
RADAR SYSTEM
135
LASER TRACKING SYSTEM
DATA
141
SECOND FLEXIBLE MANUFACTURING SYSTEM
152
THIRD FLEXIBLE MANUFACTURING SYSTEM
154

FIG. 1

FIG. 2


114
102
FUSELAGE
FUSELAGE ASSEMBLY
EXTERIOR
NUMBER OF FLOORS
266
234
SIDES 204
CROWN
KEEL
FIRST SIDE
SECOND SIDE
205
200
202
206
208
PLURALITY OF FUSELAGE SECTIONS
FUSELAGE SECTION 207
BULKHEAD
272
120
218
CROWN PANELS
PLURALITY OF PANELS
220
228
FIRST SURFACE
KEEL PANELS
SIDE PANELS
END PANEL
230
232
FIRST SIDE PANELS
SECOND SIDE PANELS
222
PANEL
SECOND SURFACE
216
224
226
240 CORRESPONDING PORTION
238 SUPPORT SECTION
242 SUPPORT MEMBERS
244 CONNECTING MEMBERS
246
FRAMES
SHEAR CLIPS
256
PLURALITY OF FASTENERS
248
STRINGERS
TIES
258
250
STIFFENERS
SPLICES
260
264
252
STANCHIONS
254
INTERCOSTAL STRUCTURAL MEMBERS
INTERCOSTAL CONNECTING MEMBERS
262
122 PLURALITY OF MEMBERS
121
SUPPORT STRUCTURE
236
INTERIOR

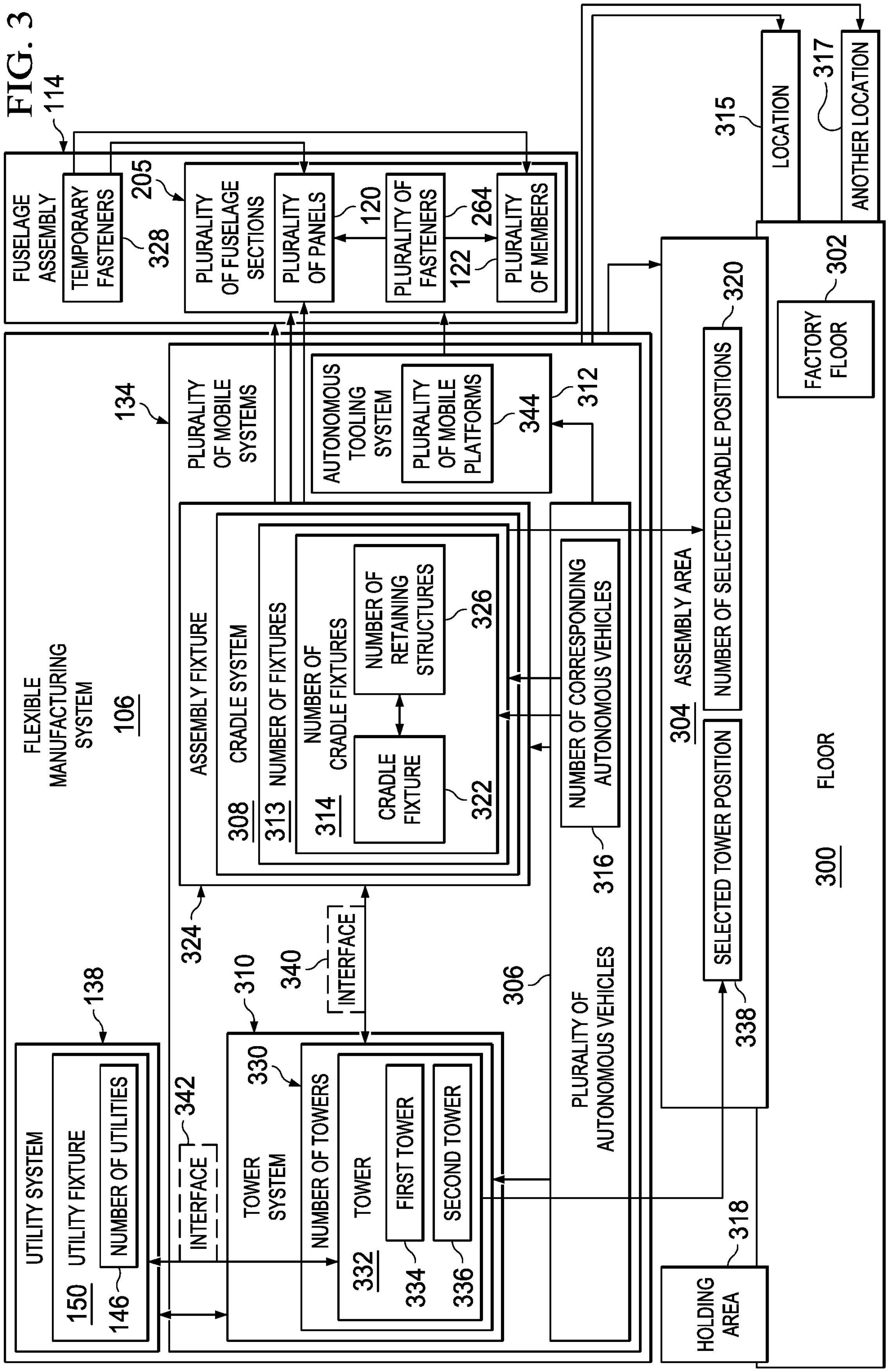
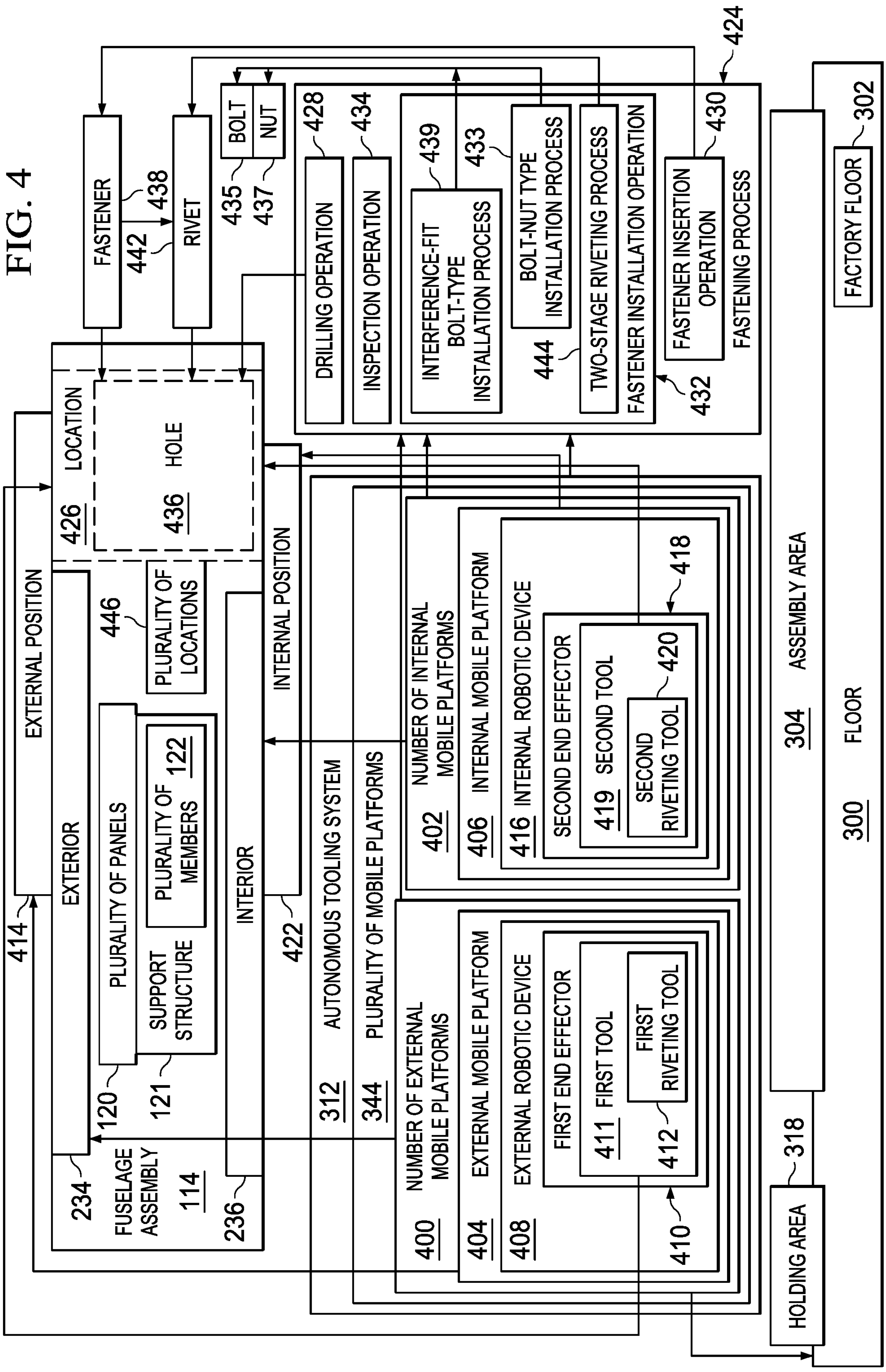

FUSELAGE ASSEMBLY
114
TEMPORARY FASTENERS
328
PLURALITY OF FUSELAGE SECTIONS
205
PLURALITY OF PANELS
120
PLURALITY OF FASTENERS
122
264
PLURALITY OF MEMBERS
LOCATION
315
ANOTHER LOCATION
317
FLEXIBLE MANUFACTURING SYSTEM
106
PLURALITY OF MOBILE SYSTEMS
134
AUTONOMOUS TOOLING SYSTEM
PLURALITY OF MOBILE PLATFORMS
344
312
ASSEMBLY FIXTURE
324
CRADLE SYSTEM
308
NUMBER OF FIXTURES
313
NUMBER OF CRADLE FIXTURES
314
CRADLE FIXTURE
322
NUMBER OF RETAINING STRUCTURES
326
NUMBER OF CORRESPONDING AUTONOMOUS VEHICLES
316
PLURALITY OF AUTONOMOUS VEHICLES
306
UTILITY SYSTEM
138
UTILITY FIXTURE
150
NUMBER OF UTILITIES
146
INTERFACE
342
TOWER SYSTEM
310
INTERFACE
340
NUMBER OF TOWERS
330
TOWER
332
FIRST TOWER
334
SECOND TOWER
336
ASSEMBLY AREA
304
NUMBER OF SELECTED CRADLE POSITIONS
320
SELECTED TOWER POSITION
338
FACTORY FLOOR
302
FLOOR
300
HOLDING AREA
318

FIG. 3

FIG. 4



FASTENER
438
442
RIVET
435
437
BOLT
NUT
428
DRILLING OPERATION
434
INSPECTION OPERATION
439
INTERFERENCE-FIT BOLT-TYPE INSTALLATION PROCESS
433
BOLT-NUT TYPE INSTALLATION PROCESS
444
TWO-STAGE RIVETING PROCESS
FASTENER INSTALLATION OPERATION
432
430
FASTENER INSERTION OPERATION
FASTENING PROCESS
424
414
EXTERNAL POSITION
426 LOCATION
436 HOLE
446
PLURALITY OF LOCATIONS
EXTERIOR
PLURALITY OF PANELS
PLURALITY OF MEMBERS 122
SUPPORT STRUCTURE
120
121
INTERIOR
INTERNAL POSITION
422
234
FUSELAGE ASSEMBLY
114
236
312 AUTONOMOUS TOOLING SYSTEM
344 PLURALITY OF MOBILE PLATFORMS
402 NUMBER OF INTERNAL MOBILE PLATFORMS
406 INTERNAL MOBILE PLATFORM
416 INTERNAL ROBOTIC DEVICE
418
SECOND END EFFECTOR
419 SECOND TOOL
420
SECOND RIVETING TOOL
400 NUMBER OF EXTERNAL MOBILE PLATFORMS
404 EXTERNAL MOBILE PLATFORM
408 EXTERNAL ROBOTIC DEVICE
410
FIRST END EFFECTOR
411 FIRST TOOL
412
FIRST RIVETING TOOL
304 ASSEMBLY AREA
318
HOLDING AREA
300 FLOOR
FACTORY FLOOR
302

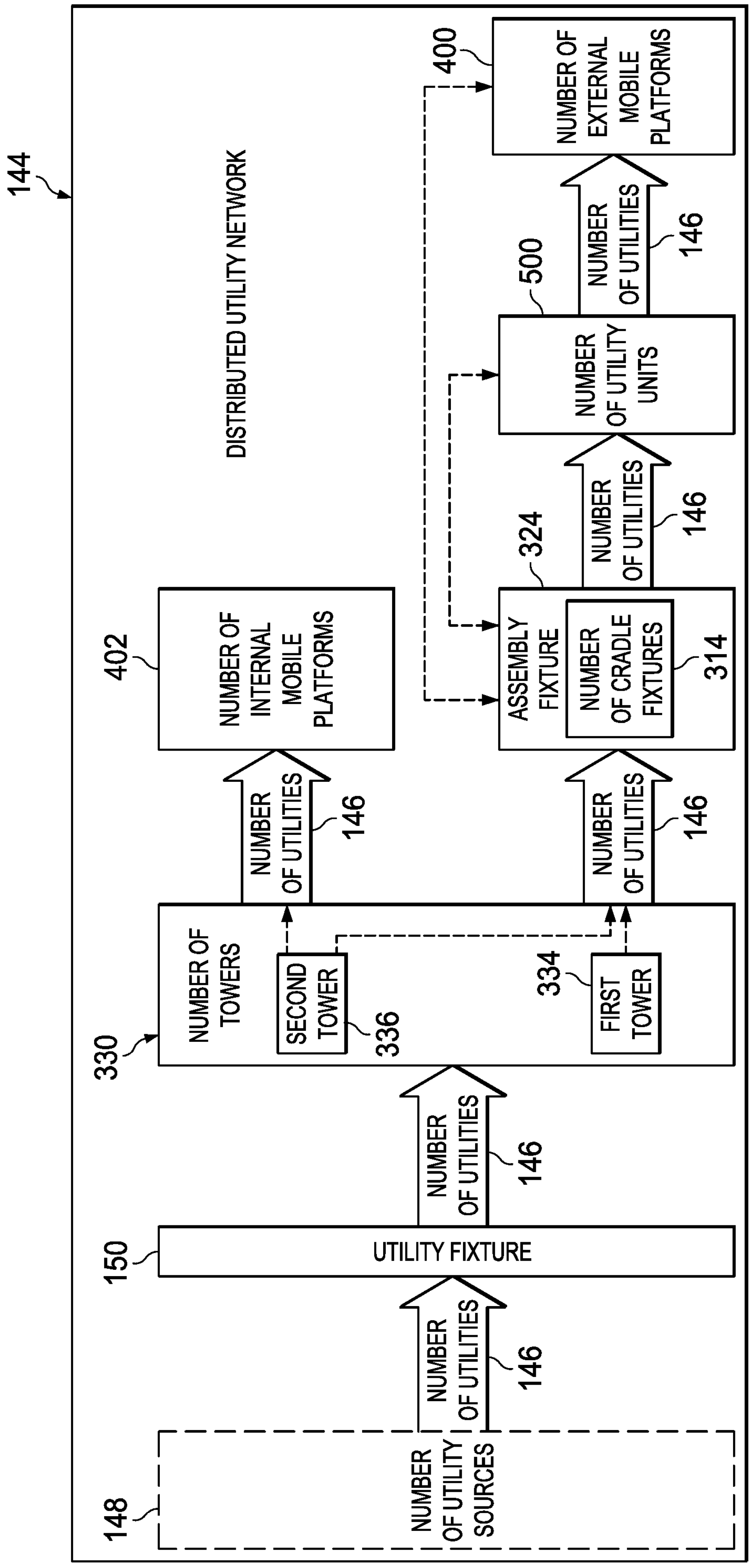
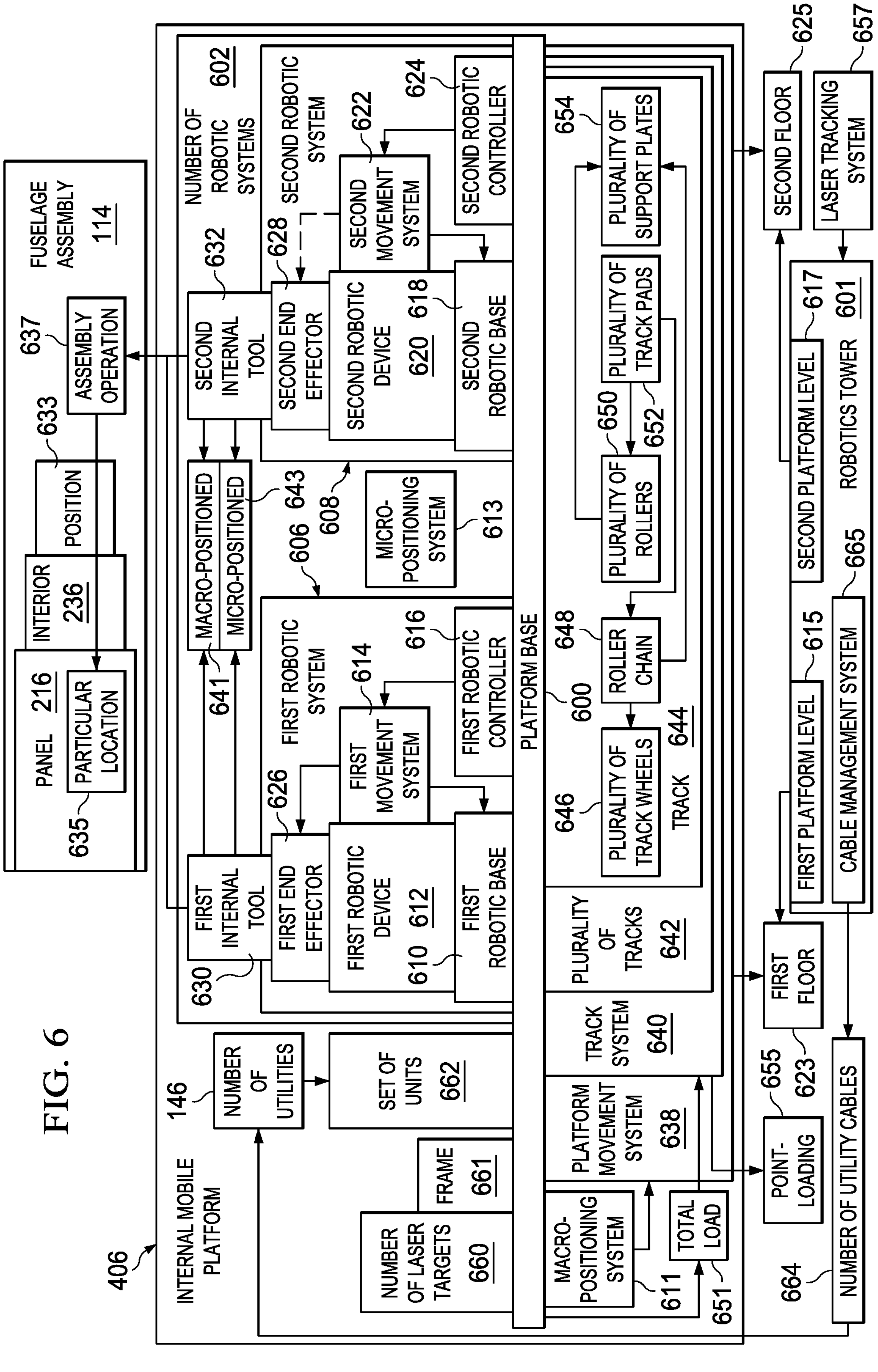

144
DISTRIBUTED UTILITY NETWORK
148
NUMBER OF UTILITY SOURCES
146
NUMBER OF UTILITIES
150
UTILITY FIXTURE
330
NUMBER OF TOWERS
SECOND TOWER
336
FIRST TOWER
334
402
NUMBER OF INTERNAL MOBILE PLATFORMS
324
ASSEMBLY FIXTURE
NUMBER OF CRADLE FIXTURES
314
500
NUMBER OF UTILITY UNITS
400
NUMBER OF EXTERNAL MOBILE PLATFORMS

FIG. 5



FUSELAGE ASSEMBLY 114
PANEL 216
PARTICULAR LOCATION
635
INTERIOR 236
POSITION
633
ASSEMBLY OPERATION
637
406
INTERNAL MOBILE PLATFORM
NUMBER OF ROBOTIC SYSTEMS 602
FIRST ROBOTIC SYSTEM
606
FIRST INTERNAL TOOL
630
FIRST END EFFECTOR
626
FIRST ROBOTIC DEVICE
610 612
FIRST MOVEMENT SYSTEM
614
FIRST ROBOTIC BASE
FIRST ROBOTIC CONTROLLER
616
MACRO-POSITIONED
MICRO-POSITIONED
641
643
608
MICRO-POSITIONING SYSTEM
613
SECOND ROBOTIC SYSTEM
SECOND INTERNAL TOOL
632
SECOND END EFFECTOR
628
SECOND ROBOTIC DEVICE
620
618
SECOND MOVEMENT SYSTEM
622
SECOND ROBOTIC BASE
SECOND ROBOTIC CONTROLLER
624
PLATFORM BASE
600
NUMBER OF UTILITIES
146
SET OF UNITS 662
FRAME 661
NUMBER OF LASER TARGETS 660
MACRO-POSITIONING SYSTEM
611
TOTAL LOAD
651
PLATFORM MOVEMENT SYSTEM 638
TRACK SYSTEM 640
PLURALITY OF TRACKS 642
TRACK 644
PLURALITY OF TRACK WHEELS
646
ROLLER CHAIN
648
PLURALITY OF ROLLERS
650
PLURALITY OF TRACK PADS
652
PLURALITY OF SUPPORT PLATES
654
SECOND FLOOR
625
LASER TRACKING SYSTEM
657
ROBOTICS TOWER 601
SECOND PLATFORM LEVEL
617
FIRST PLATFORM LEVEL
615
CABLE MANAGEMENT SYSTEM
665
FIRST FLOOR
623
POINT-LOADING
655
NUMBER OF UTILITY CABLES
664

FIG. 6

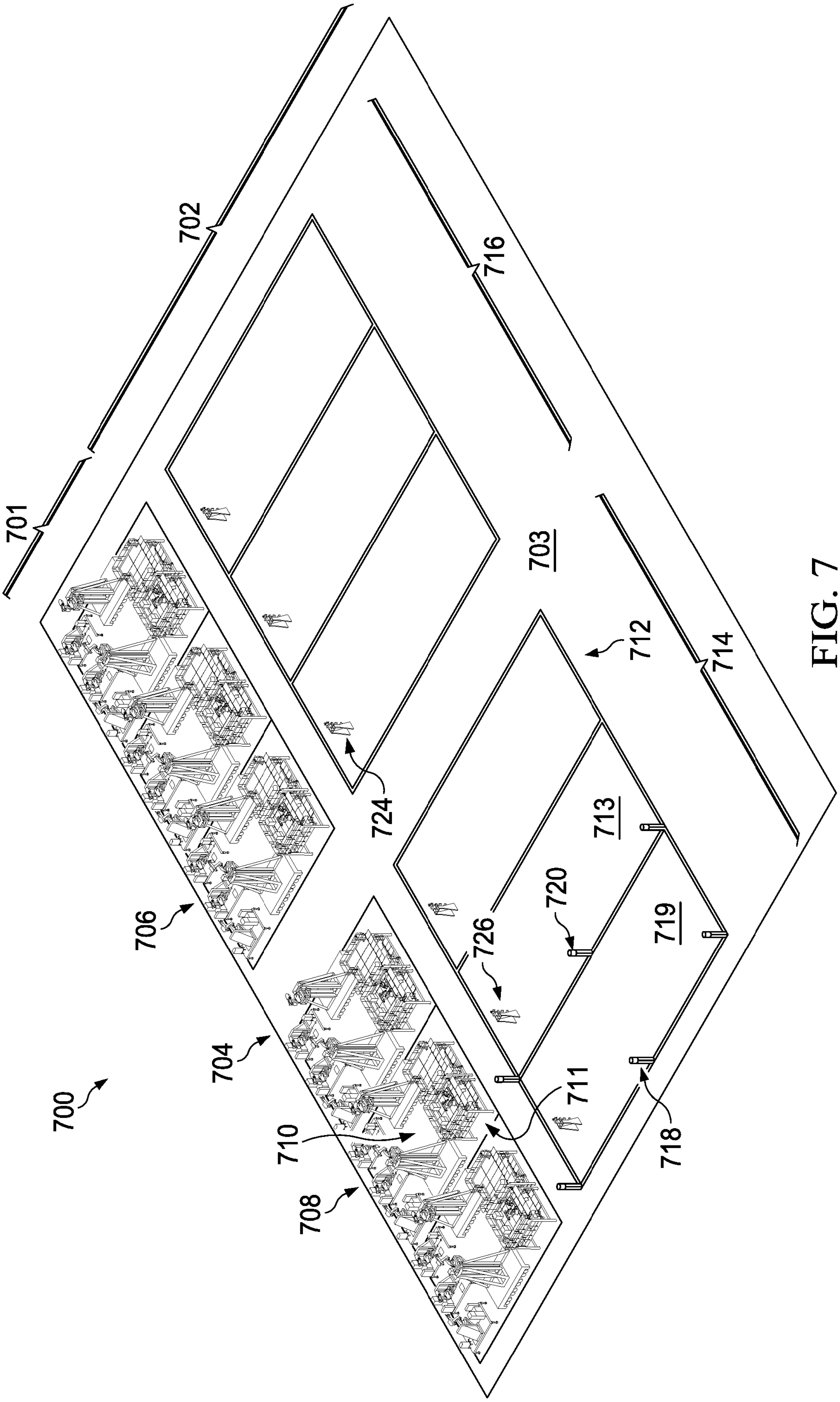

700
701
702
703
704
706
708
710
711
712
713
714
716
718
719
720
724
726

FIG. 7

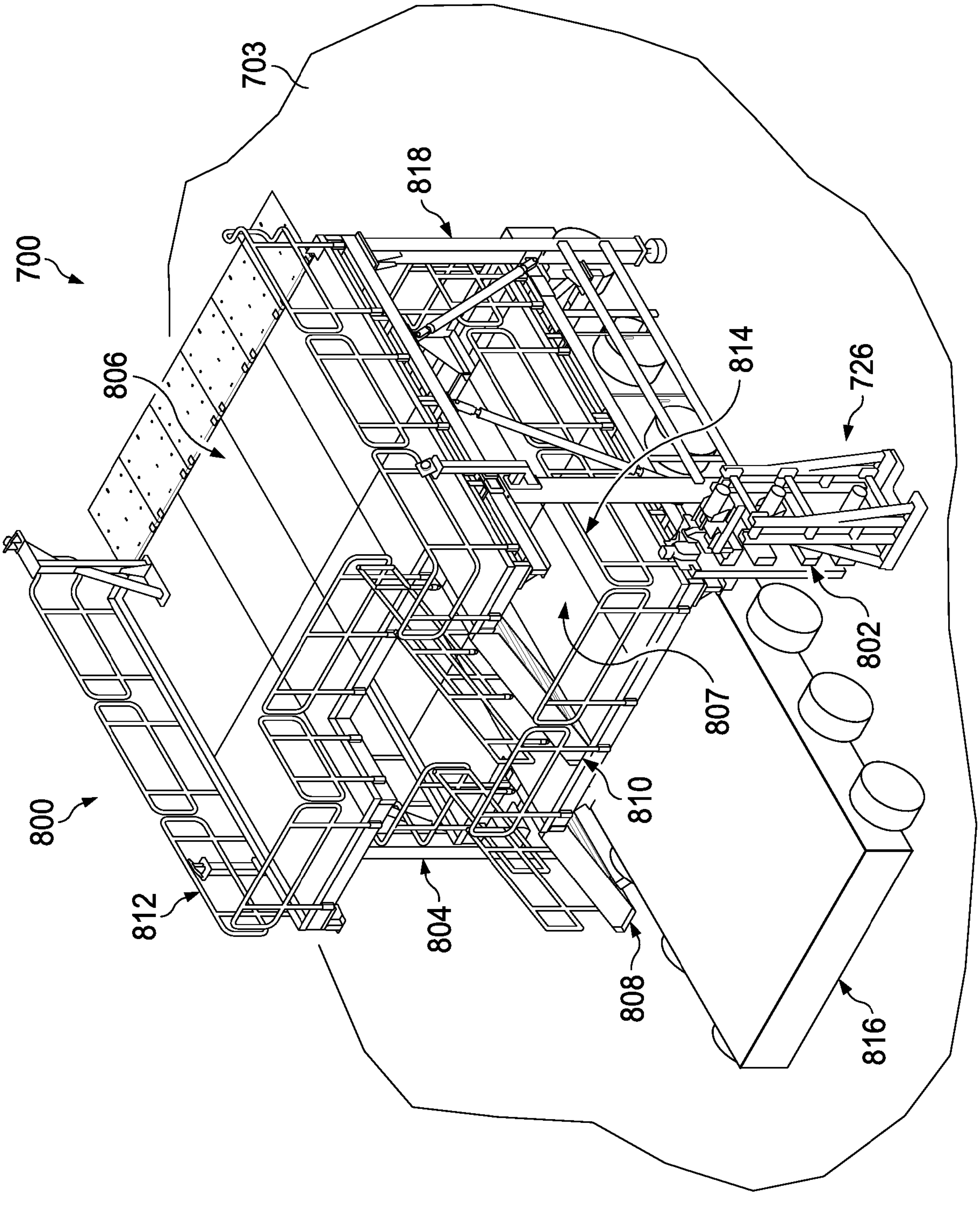


FIG. 8

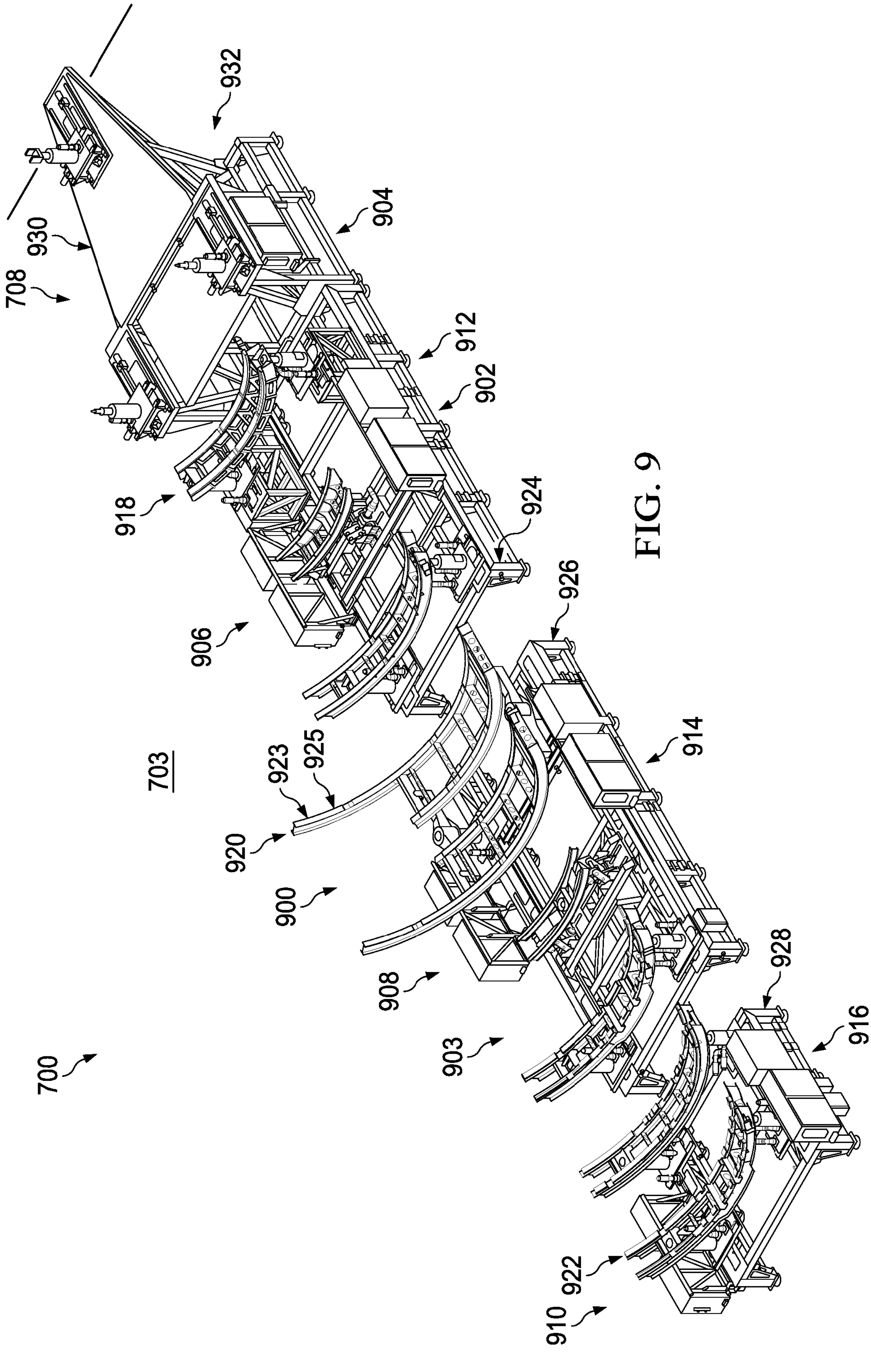

932
930
708
904
912
902
918
924
906
926
703
923
925
920
914
900
908
928
903
916
700
922
910

FIG. 9

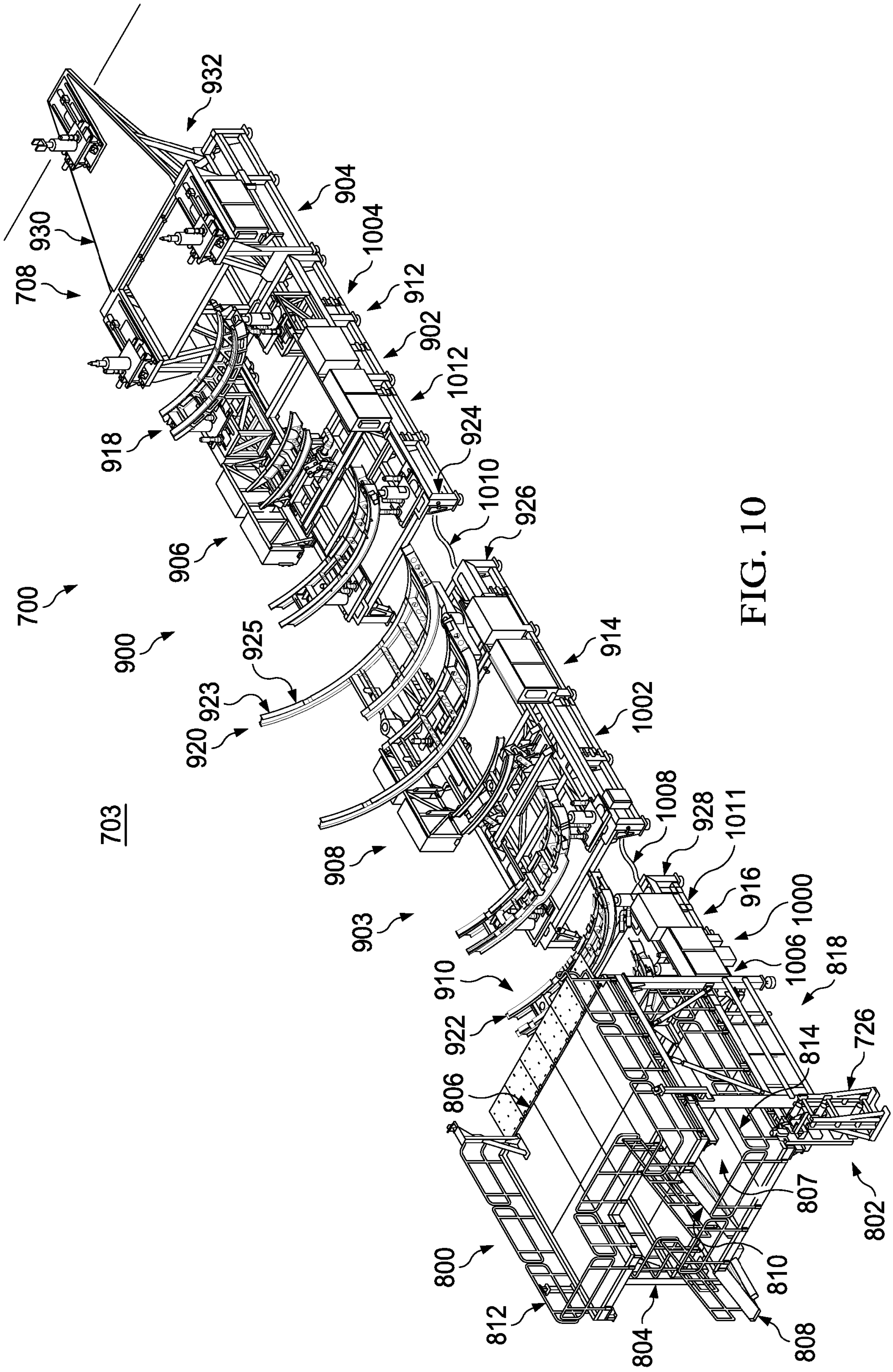

700
703
708
930
932
904
1004
912
902
1012
924
1010
926
918
906
900
925
923
920
914
1002
908
1008
928
1011
916
1000
1006
818
903
910
922
806
814
726
807
802
800
810
812
804
808

FIG. 10

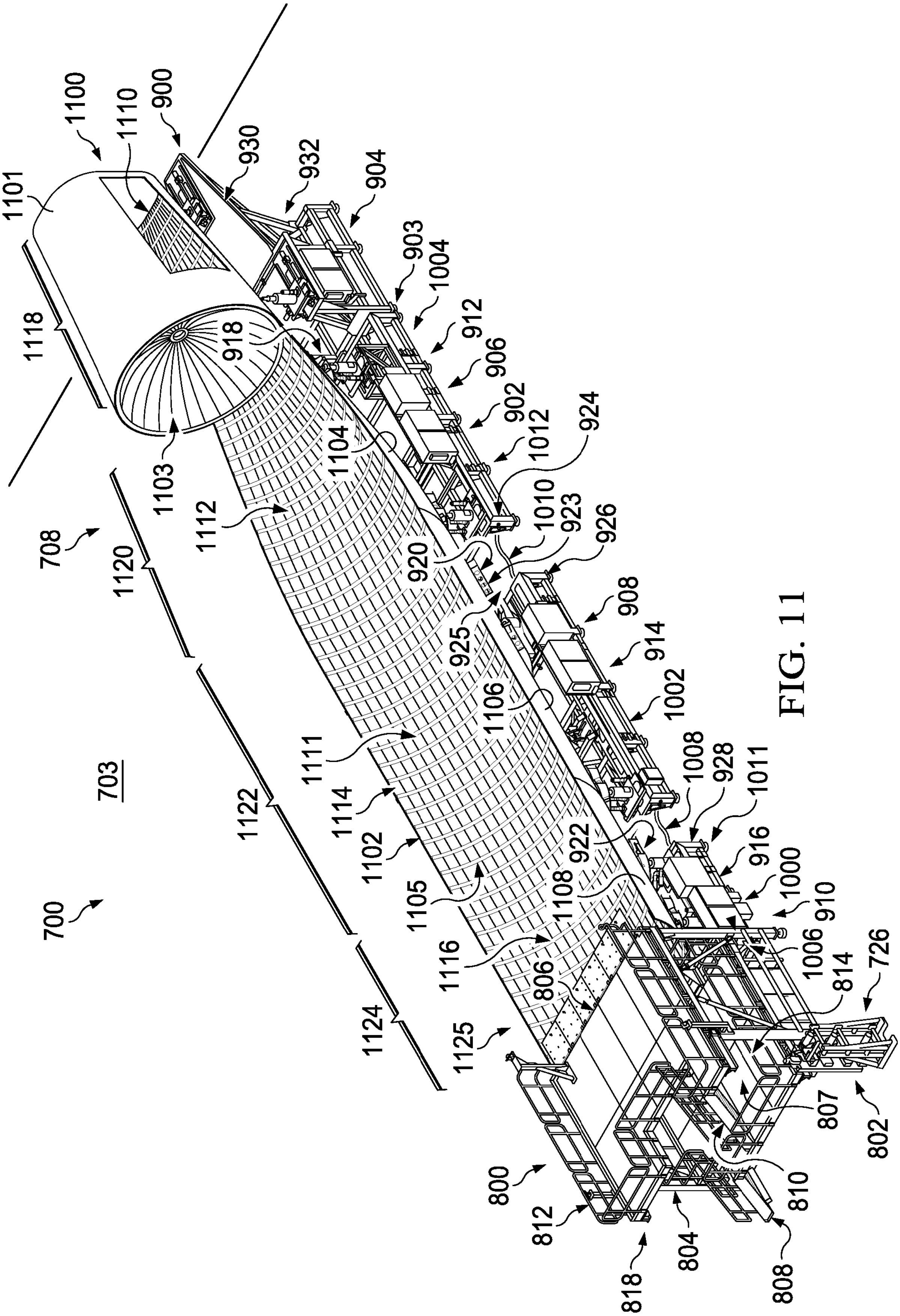

700
703
708
1100
1101
1110
900
930
932
904
903
1004
912
906
902
1012
924
1010
923
926
918
1118
1103
1104
1112
1120
920
925
908
914
1002
1106
1111
1114
1122
1102
1105
1008
928
1011
922
916
1000
910
1108
1116
1006
814
726
806
1124
1125
807
802
810
800
812
804
808
818

FIG. 11

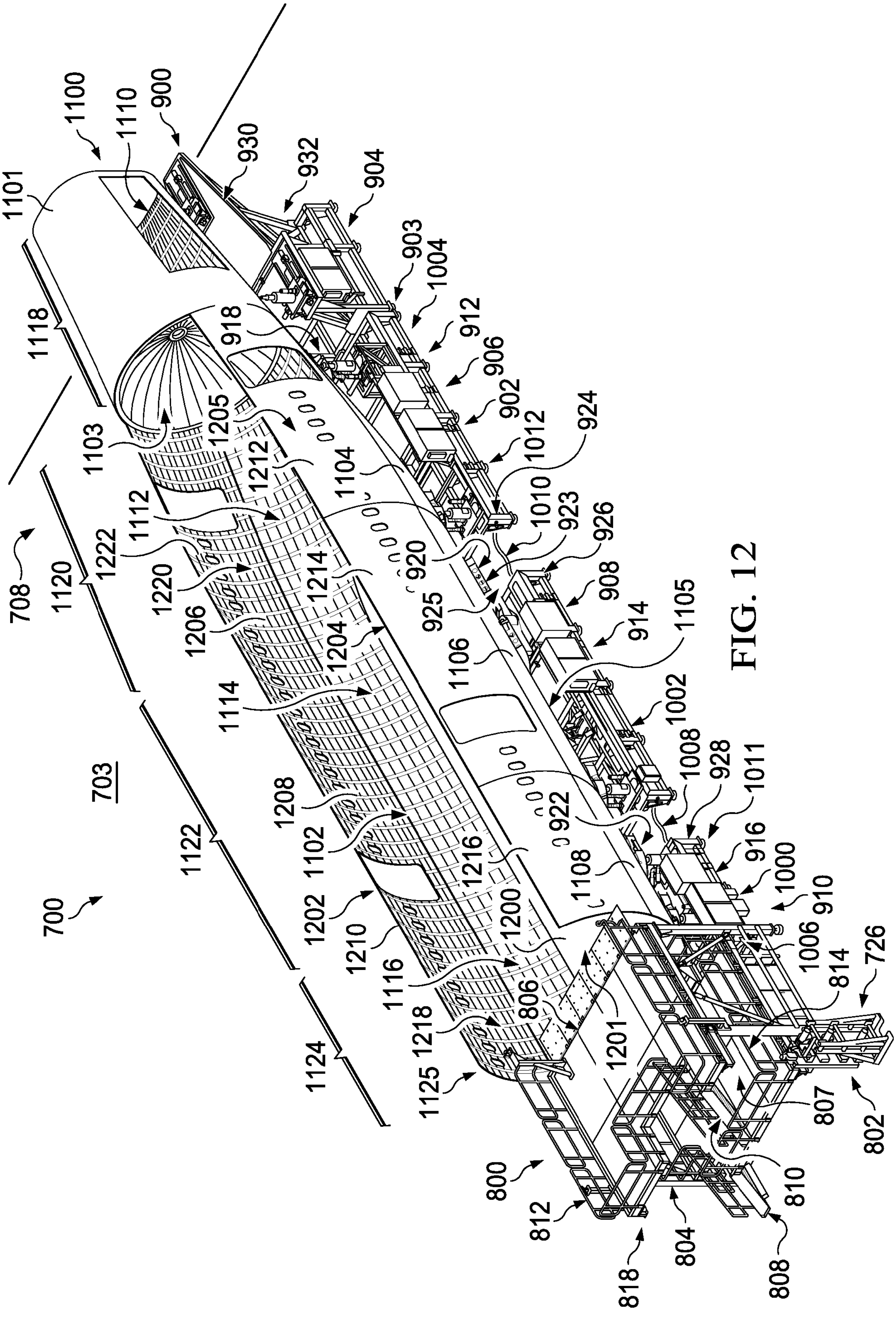

700
703
708
1100
1101
1110
900
930
932
904
903
1004
912
906
902
1012
924
1010
923
926
908
914
1105
1002
1008
928
1011
916
1000
910
1006
814
726
802
807
810
808
804
818
812
800
1118
1120
1122
1124
1125
1218
1116
806
1201
1200
1210
1202
1102
1208
1216
1108
922
1114
1204
1206
1220
1222
1112
1212
1214
920
925
1106
1104
1205
1103
918

FIG. 12

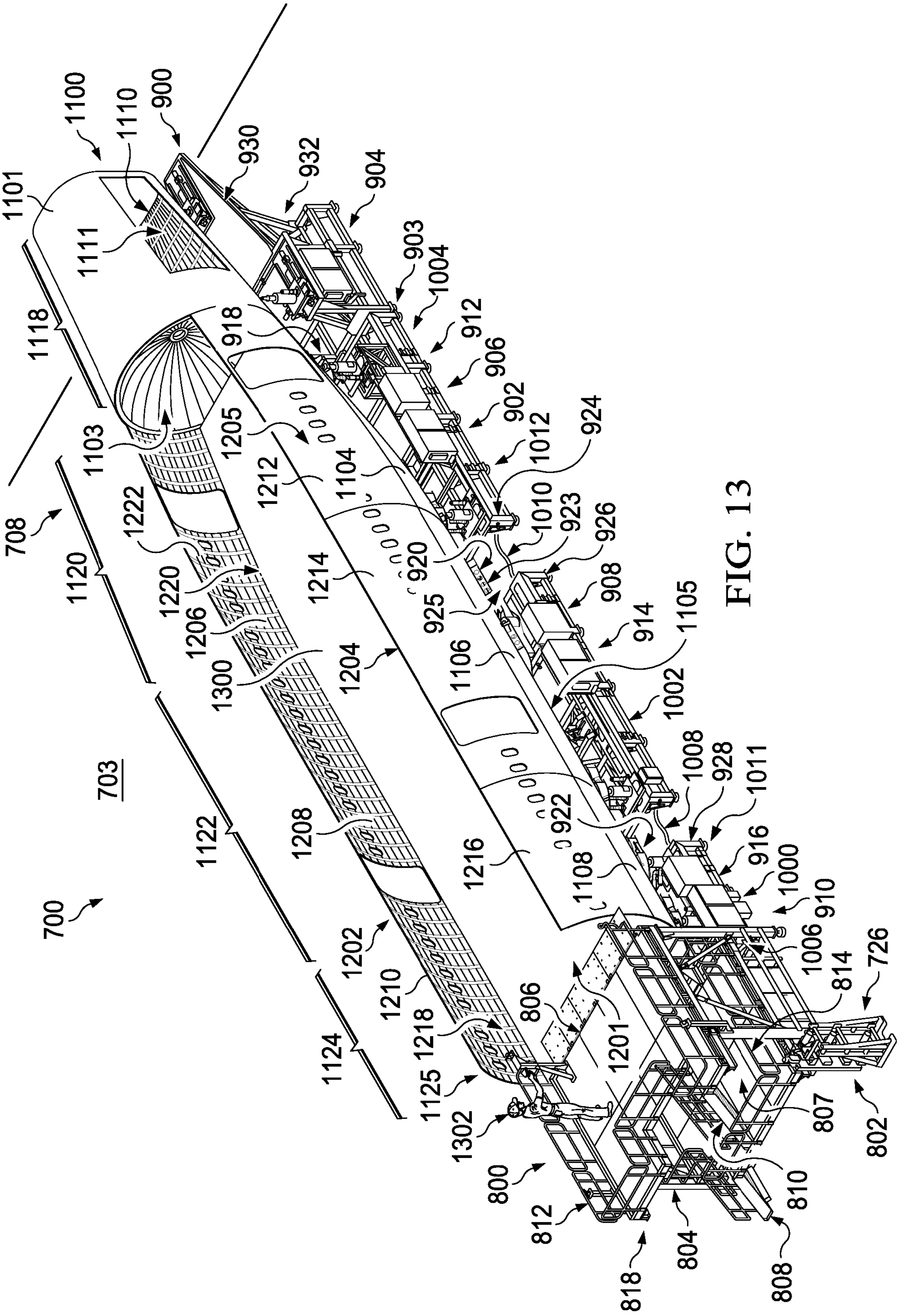

700
703
708
1100
1101
1103
1104
1105
1106
1108
1110
1111
1118
1120
1122
1124
1125
900
902
903
904
906
908
910
912
914
916
918
920
922
923
924
925
926
928
930
932
1000
1002
1004
1006
1008
1010
1011
1012
1201
1202
1204
1205
1206
1208
1210
1212
1214
1216
1218
1220
1222
1300
1302
800
802
804
806
807
808
810
812
814
818
726

FIG. 13

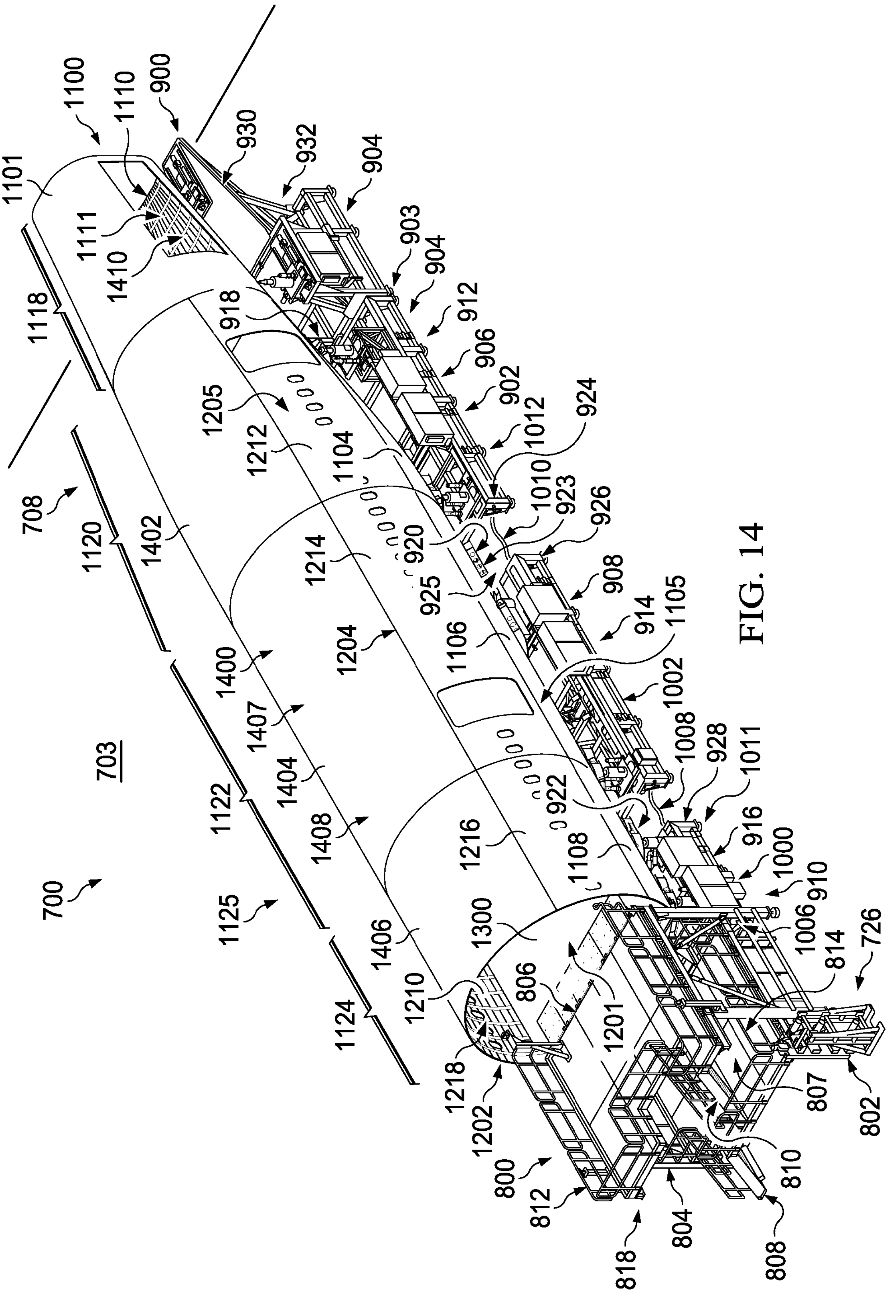

700
703
708
1100
1101
1110
1111
1410
900
930
932
904
903
904
912
906
902
1012
924
918
1118
1205
1212
1104
1010
923
926
920
1120
1402
1214
925
908
1106
914
1105
1204
1400
1407
1002
1008
928
1011
1122
1404
922
916
1408
1216
1000
910
1108
1125
1300
1006
814
726
1406
806
1124
1210
1201
1218
1202
807
802
810
800
812
804
818
808

FIG. 14

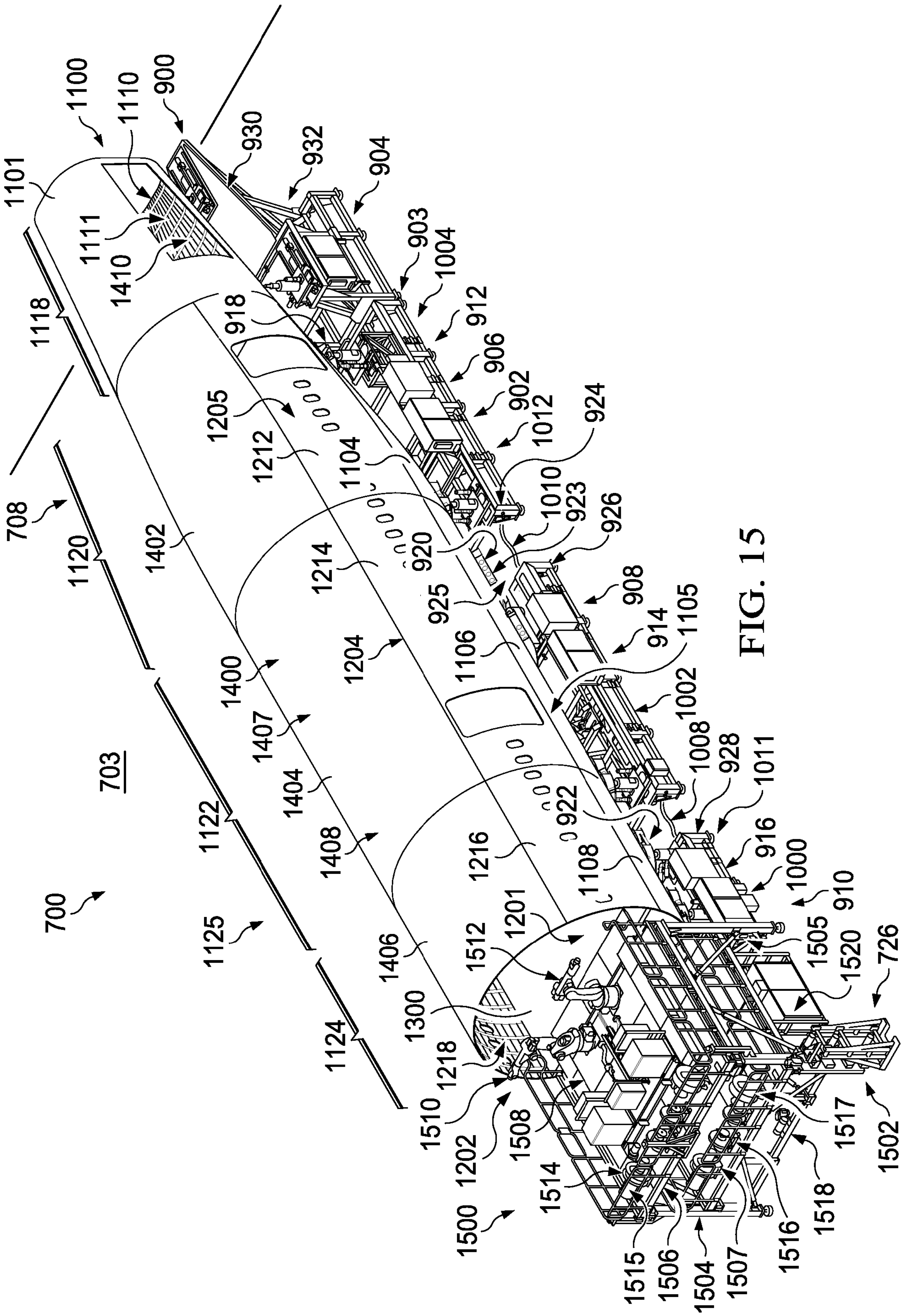

700
703
708
726
900
902
903
904
906
908
910
912
914
916
918
920
922
923
924
925
926
928
930
932
1000
1002
1004
1008
1010
1011
1012
1100
1101
1104
1105
1106
1108
1110
1111
1118
1120
1122
1124
1125
1201
1202
1204
1205
1212
1214
1216
1218
1300
1400
1402
1404
1406
1407
1408
1410
1500
1502
1504
1505
1506
1507
1508
1510
1512
1514
1515
1516
1517
1518
1520

FIG. 15

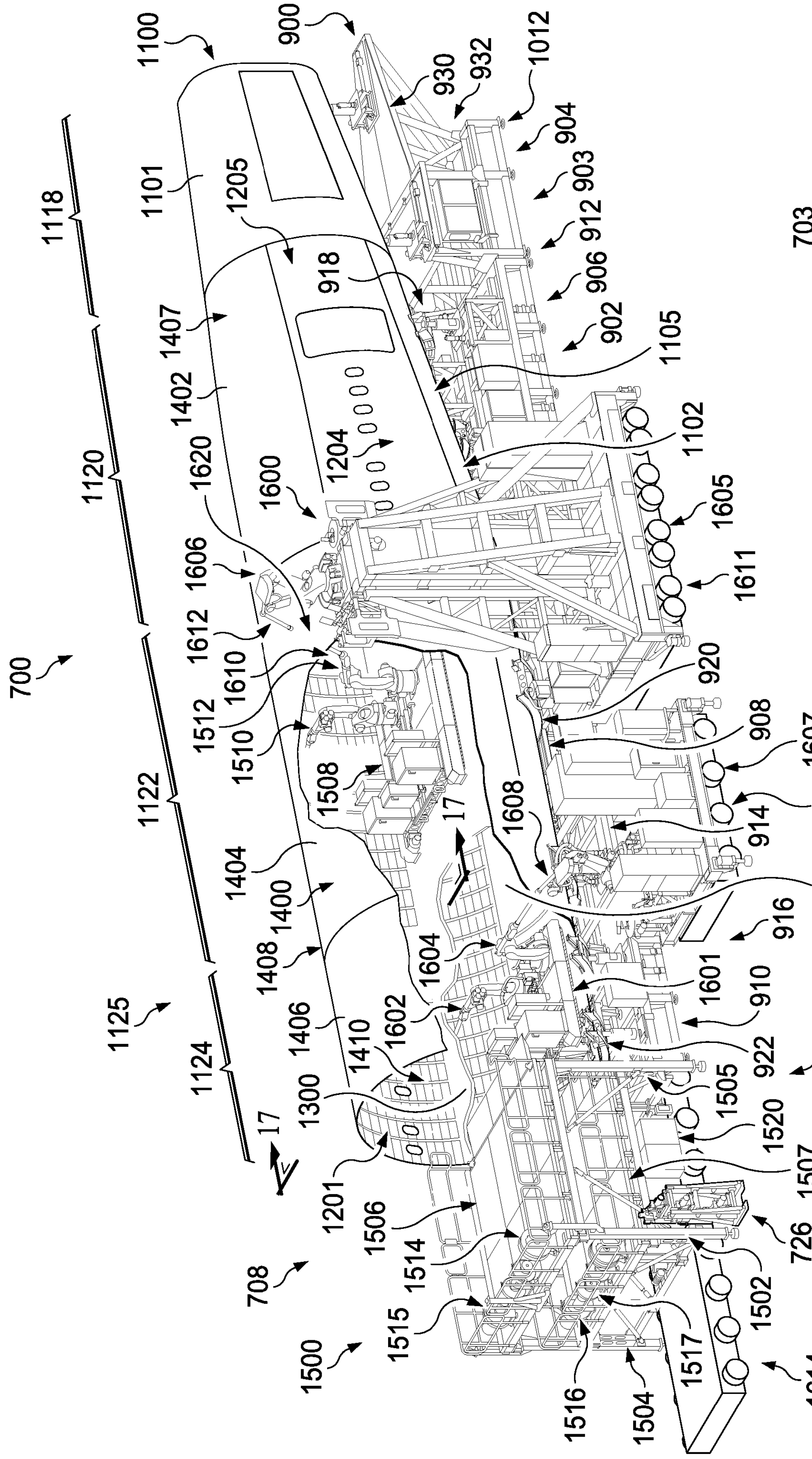

700
703
708
1100
1101
1102
1105
1118
1120
1122
1124
1125
1200
1201
1204
1205
1300
1400
1402
1404
1406
1407
1408
1410
1500
1502
1504
1505
1506
1507
1508
1510
1512
1514
1515
1516
1517
1518
1520
1600
1601
1602
1604
1605
1606
1607
1608
1610
1611
1612
1613
1614
1620
726
900
902
903
904
906
908
910
912
914
916
918
920
922
930
932
1012
17
17

FIG. 16

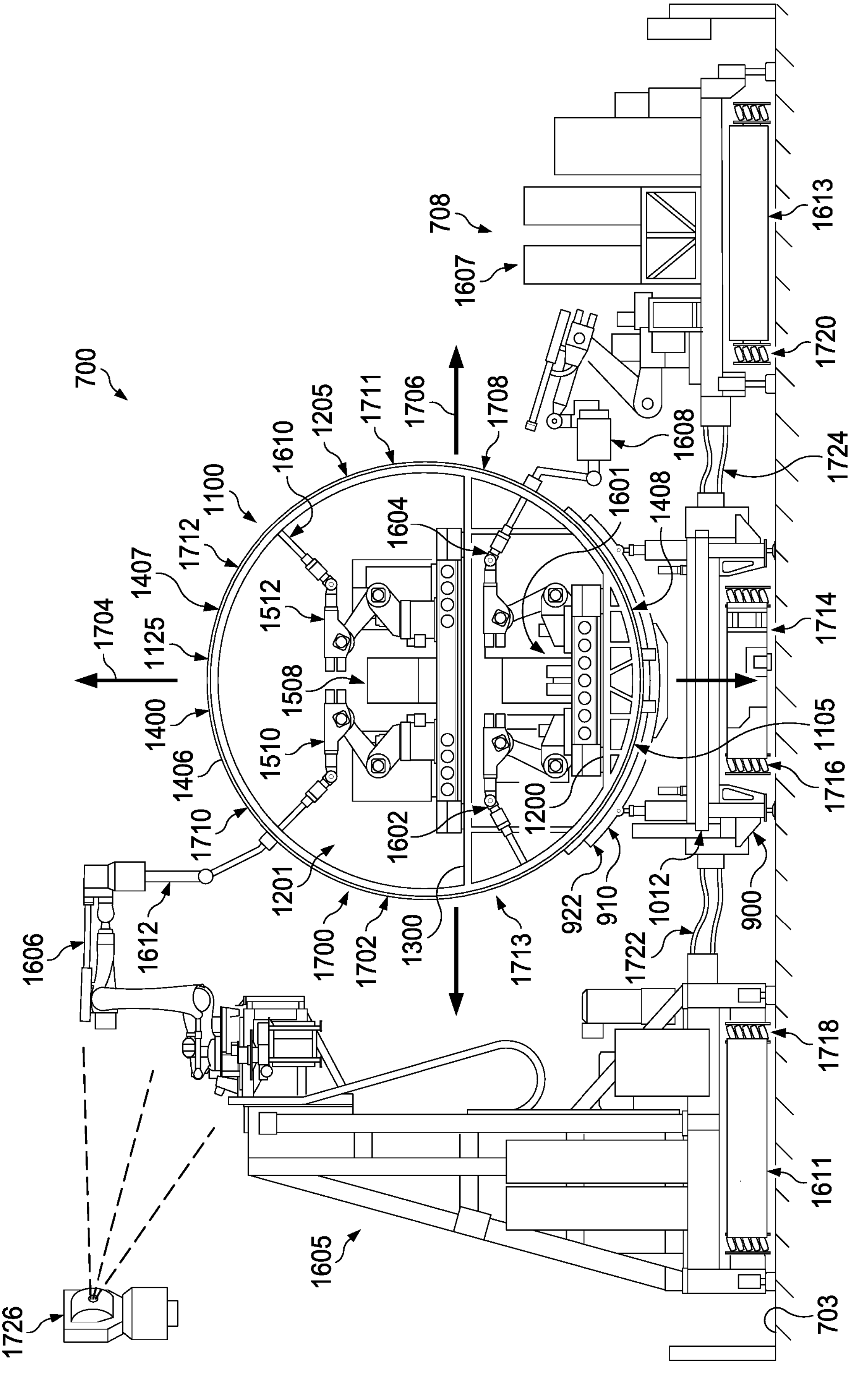

700
708
1607
1613
1720
1608
1724
1205
1711
1706
1708
1610
1100
1604
1601
1408
1712
1407
1512
1704
1125
1714
1508
1400
1105
1510
1406
1716
1200
1710
1602
1201
1300
1700
1702
1713
922
910
1012
900
1722
1612
1606
1718
1611
1605
703
1726

FIG. 17

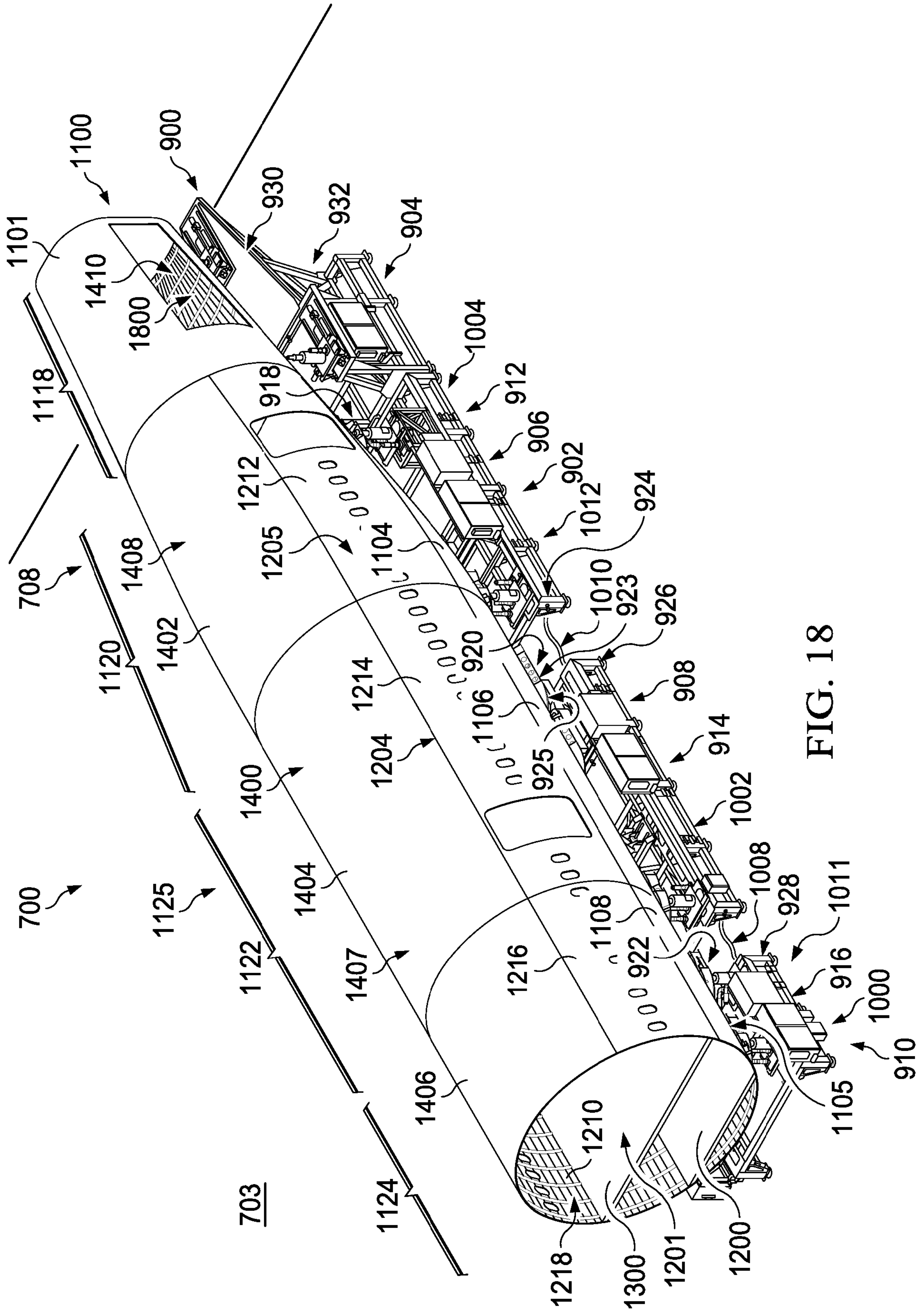

700
703
708
900
902
904
906
908
910
912
914
916
918
920
922
923
924
925
926
928
930
932
1000
1002
1004
1008
1010
1011
1012
1100
1101
1104
1105
1106
1108
1118
1120
1122
1124
1125
1200
1201
1204
1205
1210
1212
1214
1216
1218
1300
1400
1402
1404
1406
1407
1408
1410
1800

FIG. 18

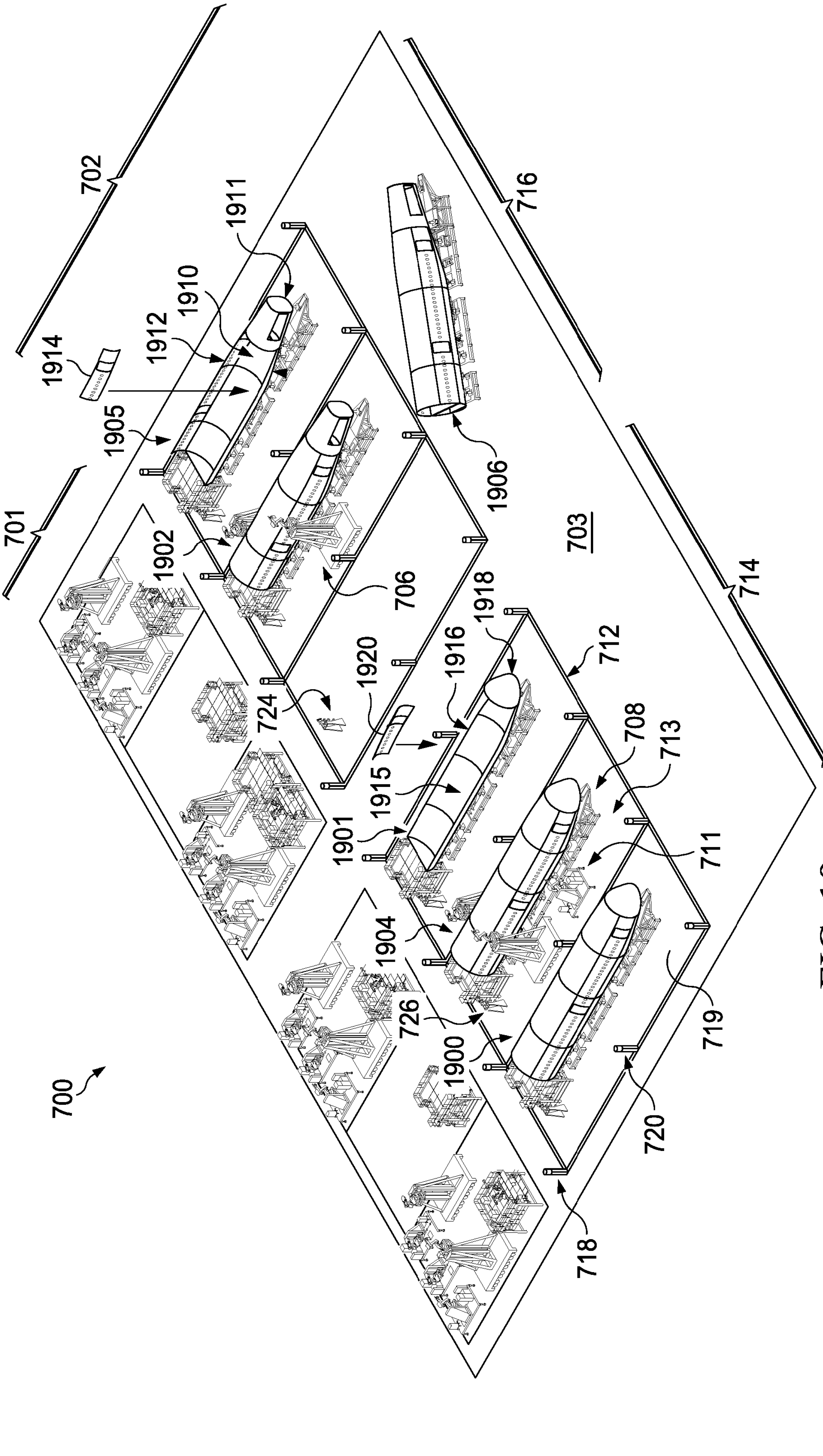

700
701
702
703
706
708
711
712
713
714
716
718
719
720
724
726
1900
1901
1902
1904
1905
1906
1910
1911
1912
1914
1915
1916
1918
1920

FIG. 19

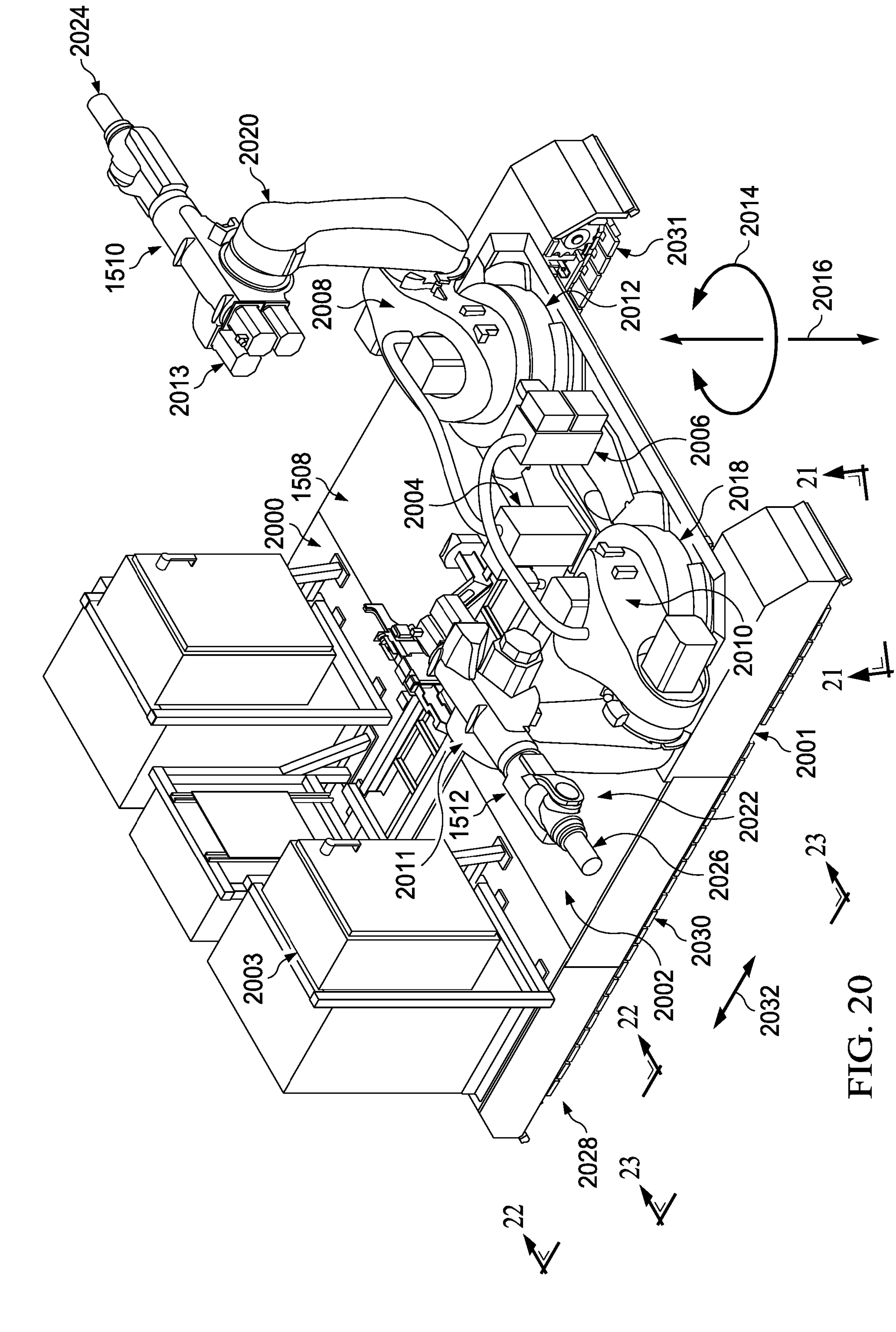

2024
2020
1510
2013
2008
2031
2014
2012
2016
2006
2018
1508
2004
2000
21
2010
21
2001
2022
1512
2011
2026
23
2003
2030
2002
2032
22
2028
23
22

FIG. 20

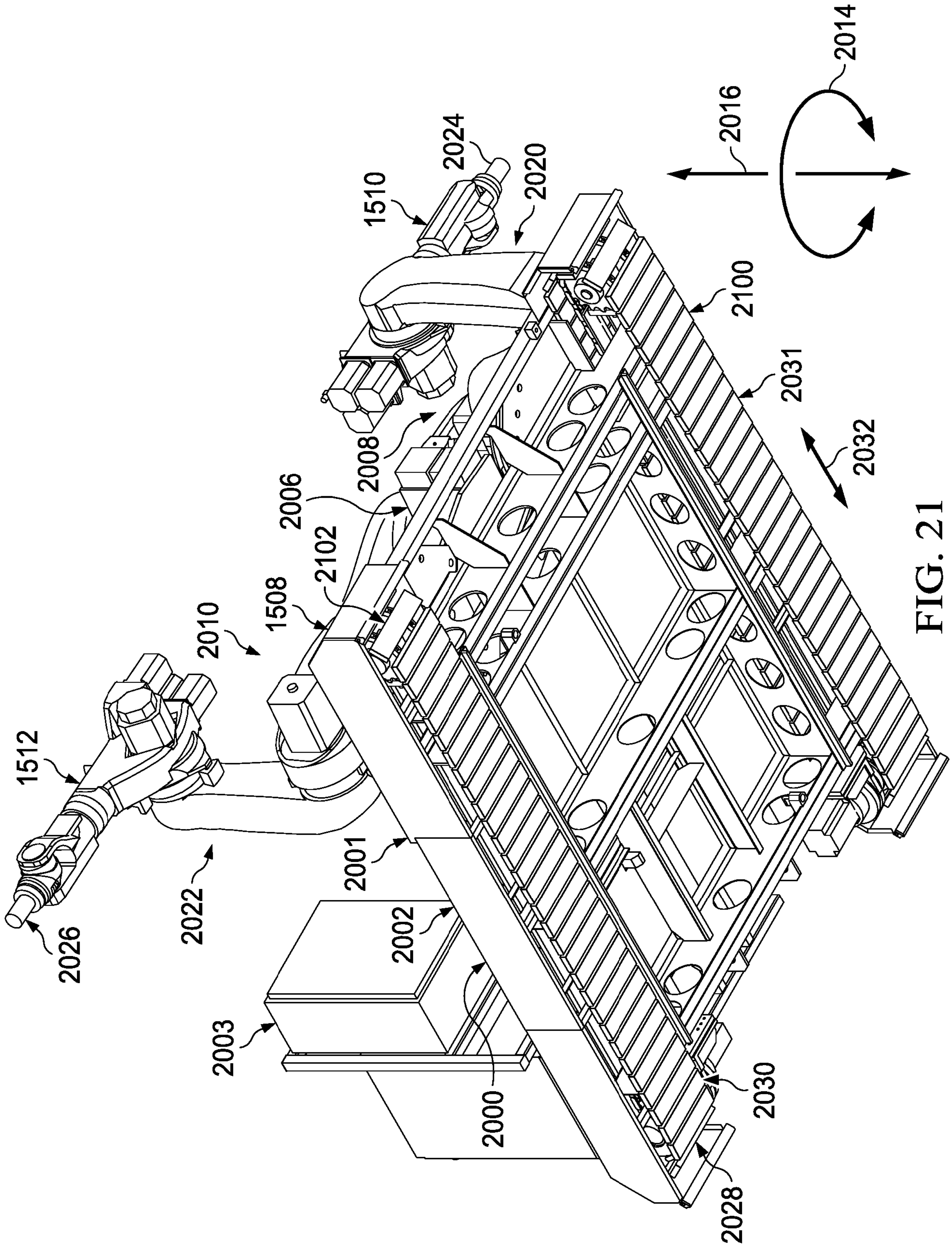

2014
2016
2024
2020
1510
2100
2031
2032
2008
2006
2102
1508
2010
1512
2022
2026
2001
2002
2003
2000
2030
2028

FIG. 21

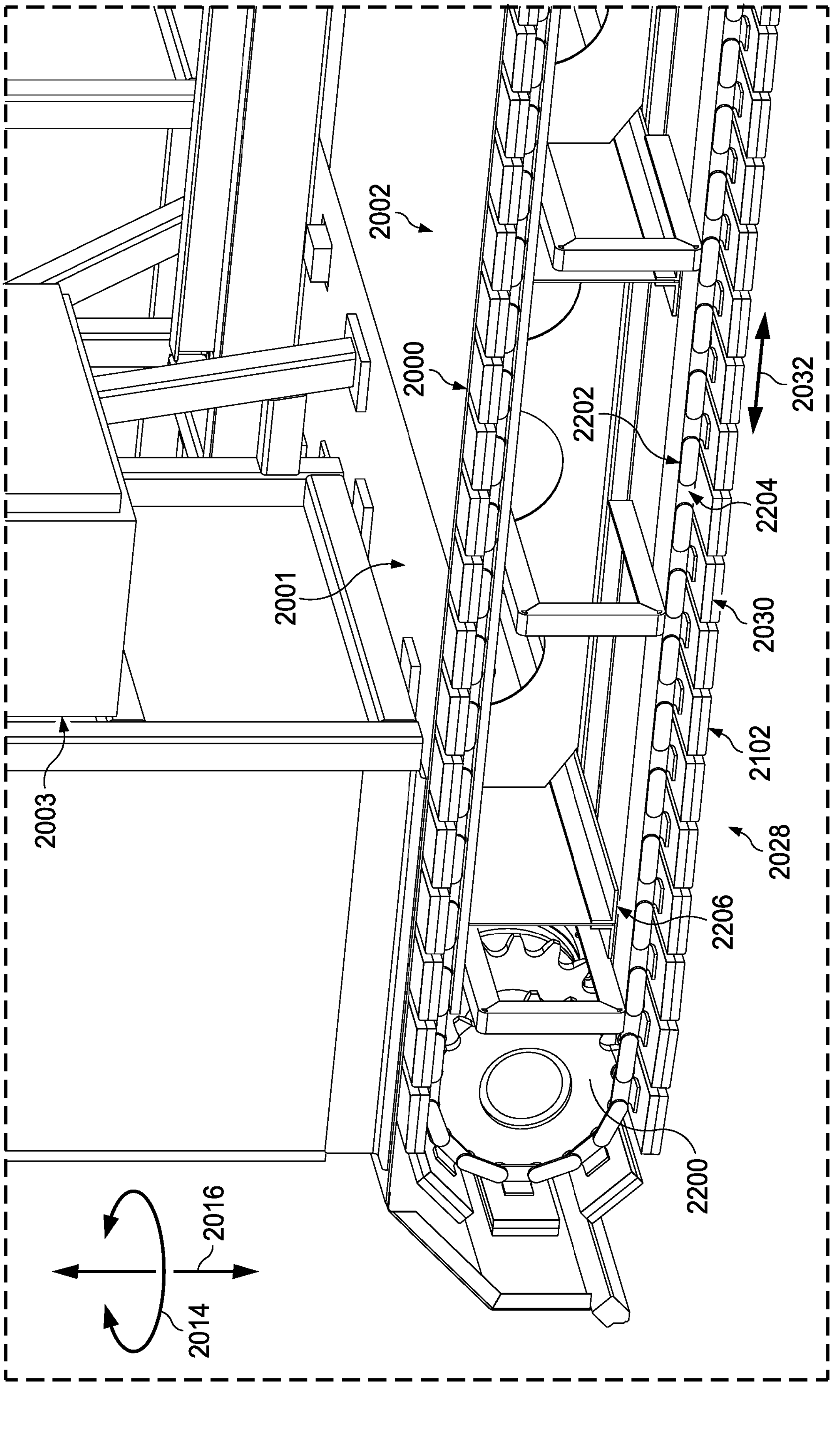

2002
2000
2001
2003
2202
2204
2032
2030
2102
2028
2206
2200
2016
2014

FIG. 22

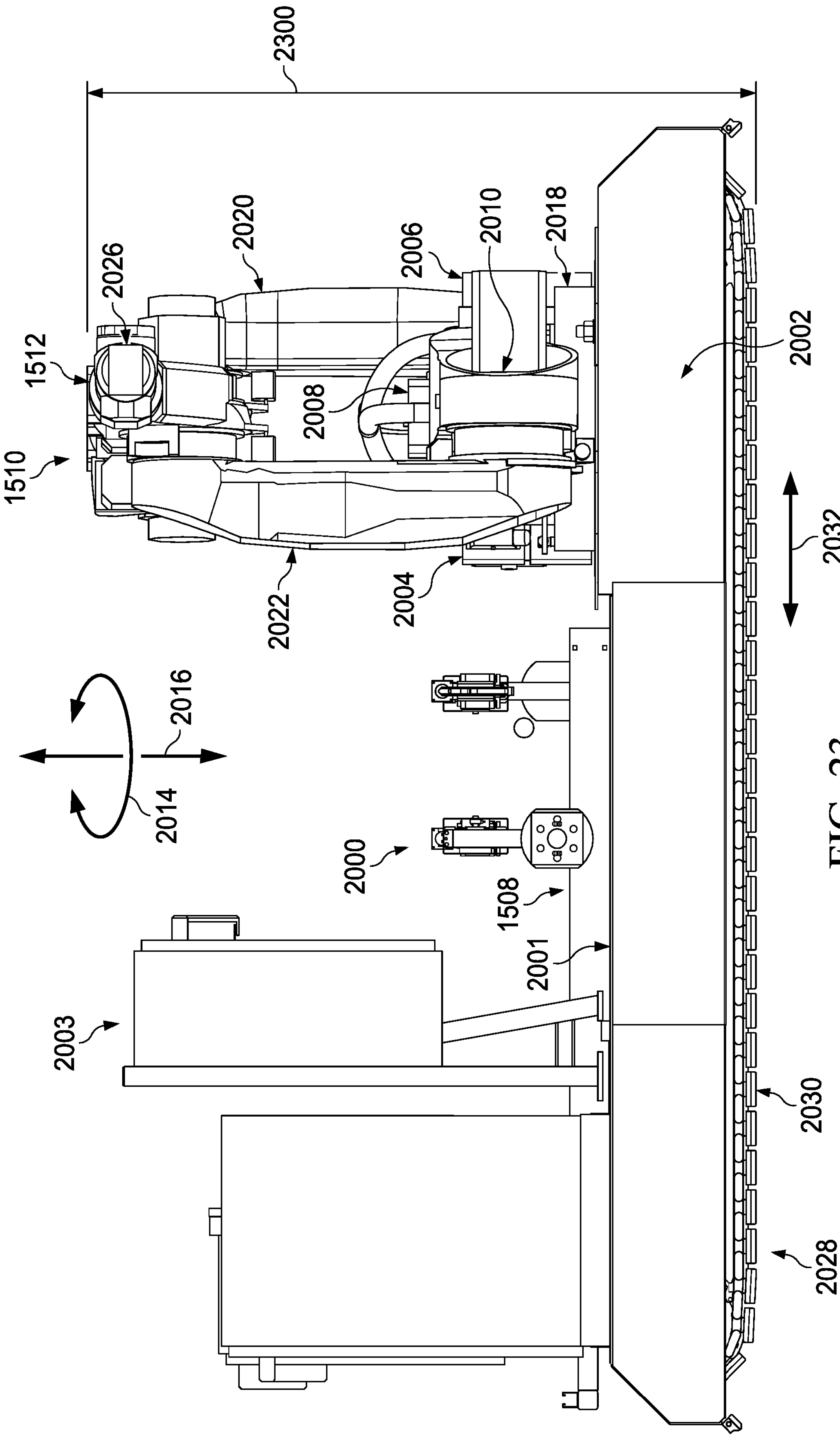

2300
2026
2020
2006
2010
2018
1512
1510
2008
2002
2032
2022
2004
2016
2014
2000
1508
2001
2003
2030
2028

FIG. 23

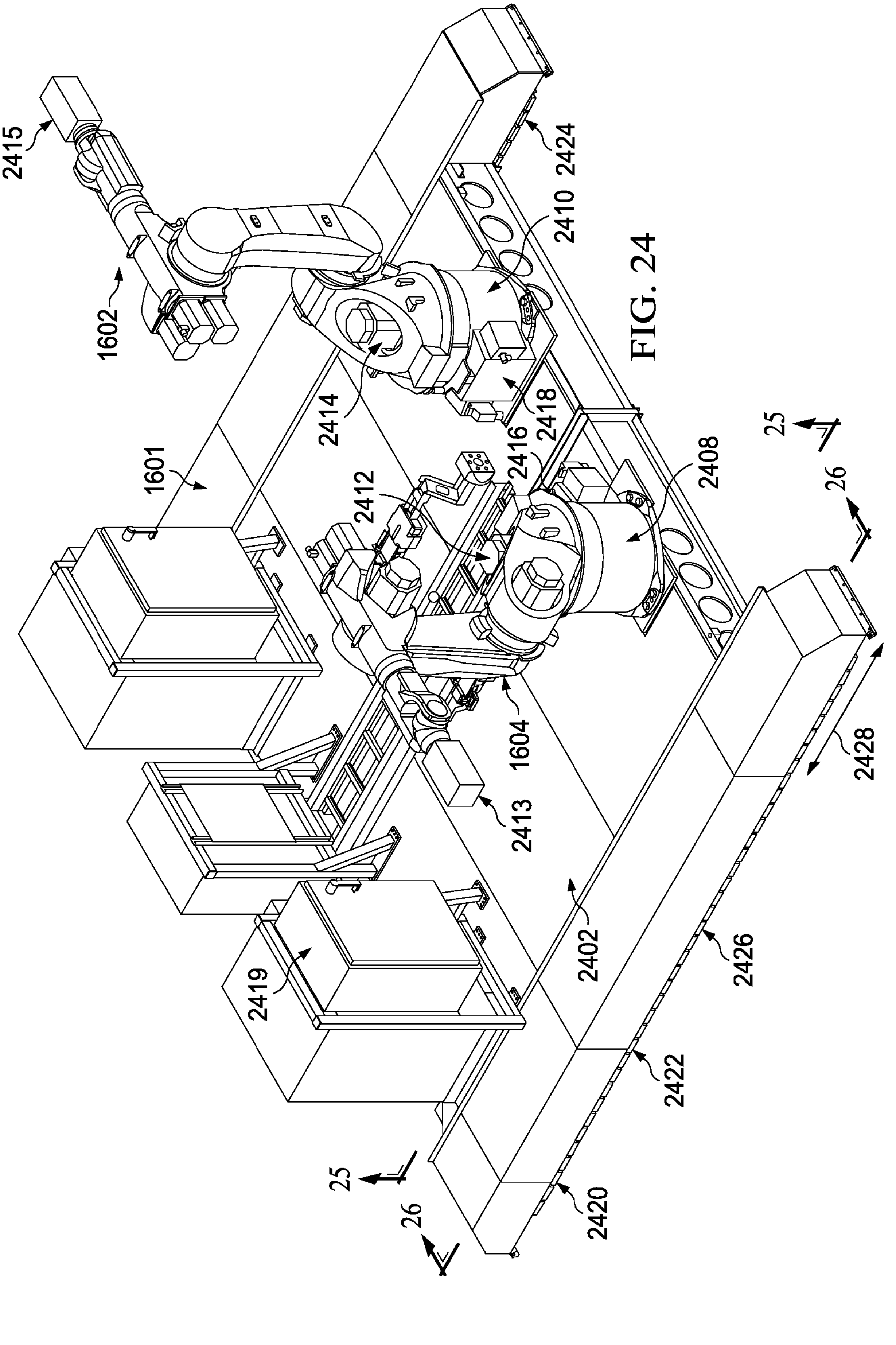

2415
1602
1601
2414
2412
2410
2424
2418
2416
2408
25
26
1604
2413
2428
2402
2426
2419
2422
2420
25
26

FIG. 24

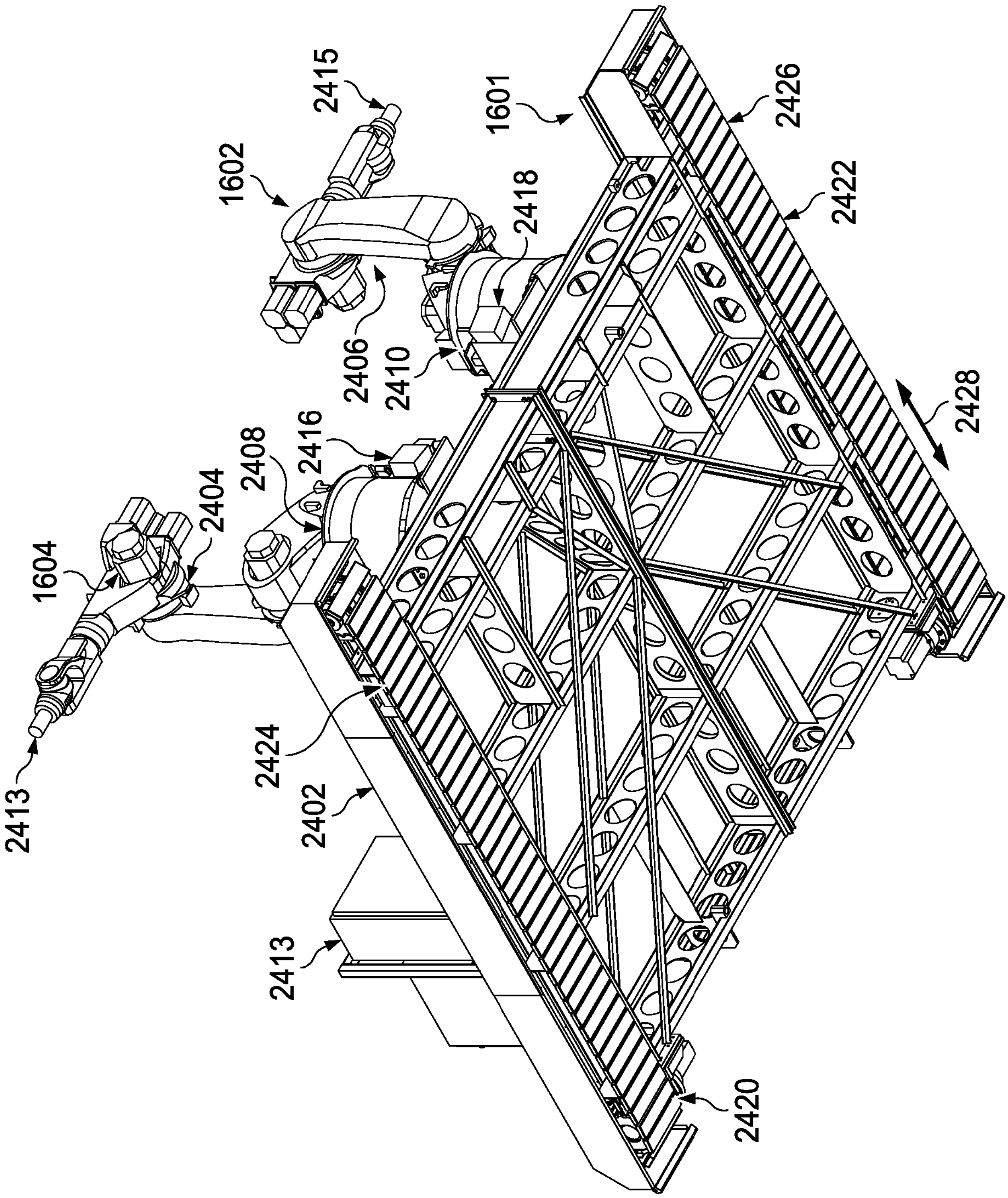

2415
1602
1601
2426
2418
2422
2406
2410
2428
2408
2416
2404
1604
2413
2424
2402
2413
2420

FIG. 25

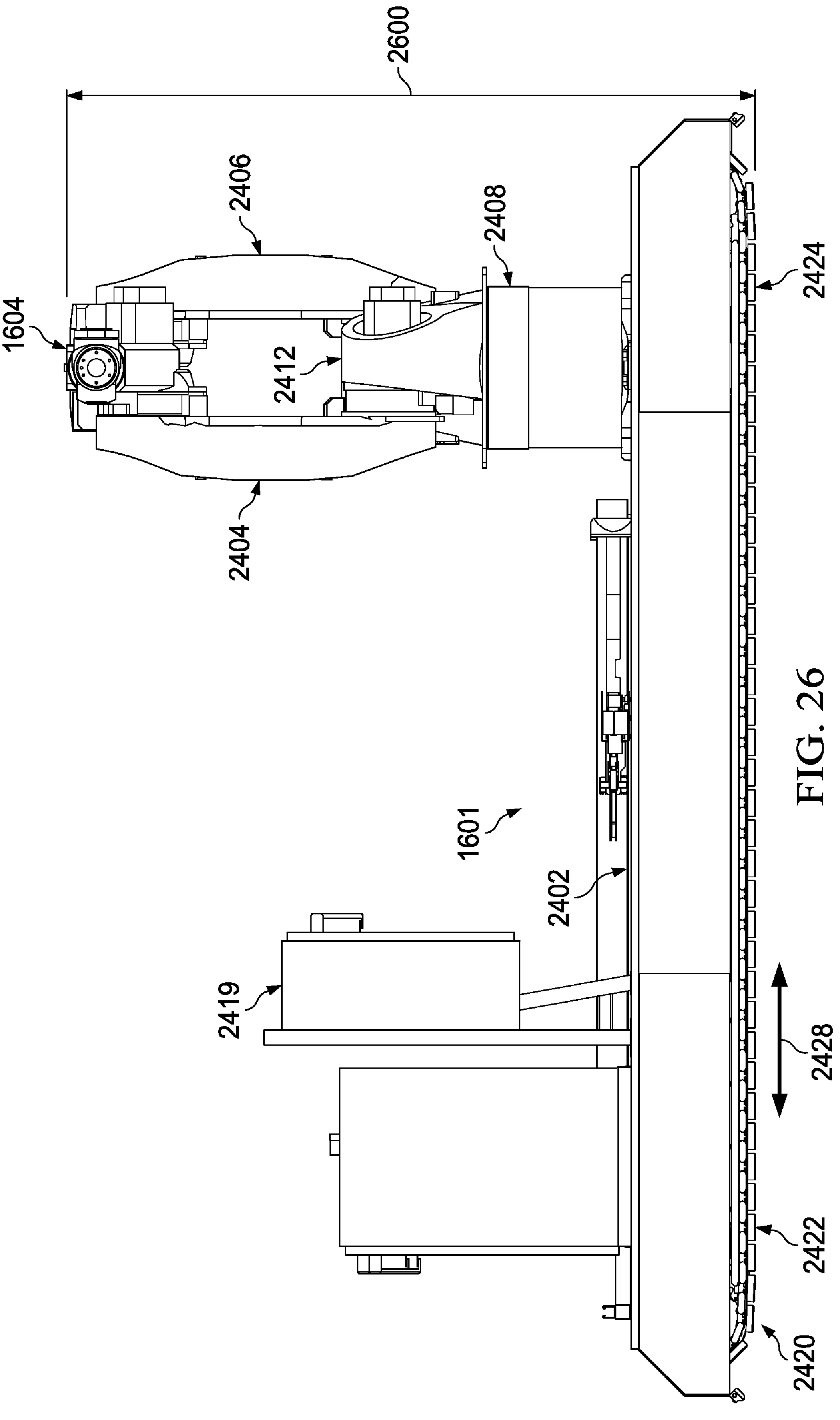

2600
2406
2408
1604
2412
2424
2404
1601
2402
2419
2428
2422
2420

FIG. 26

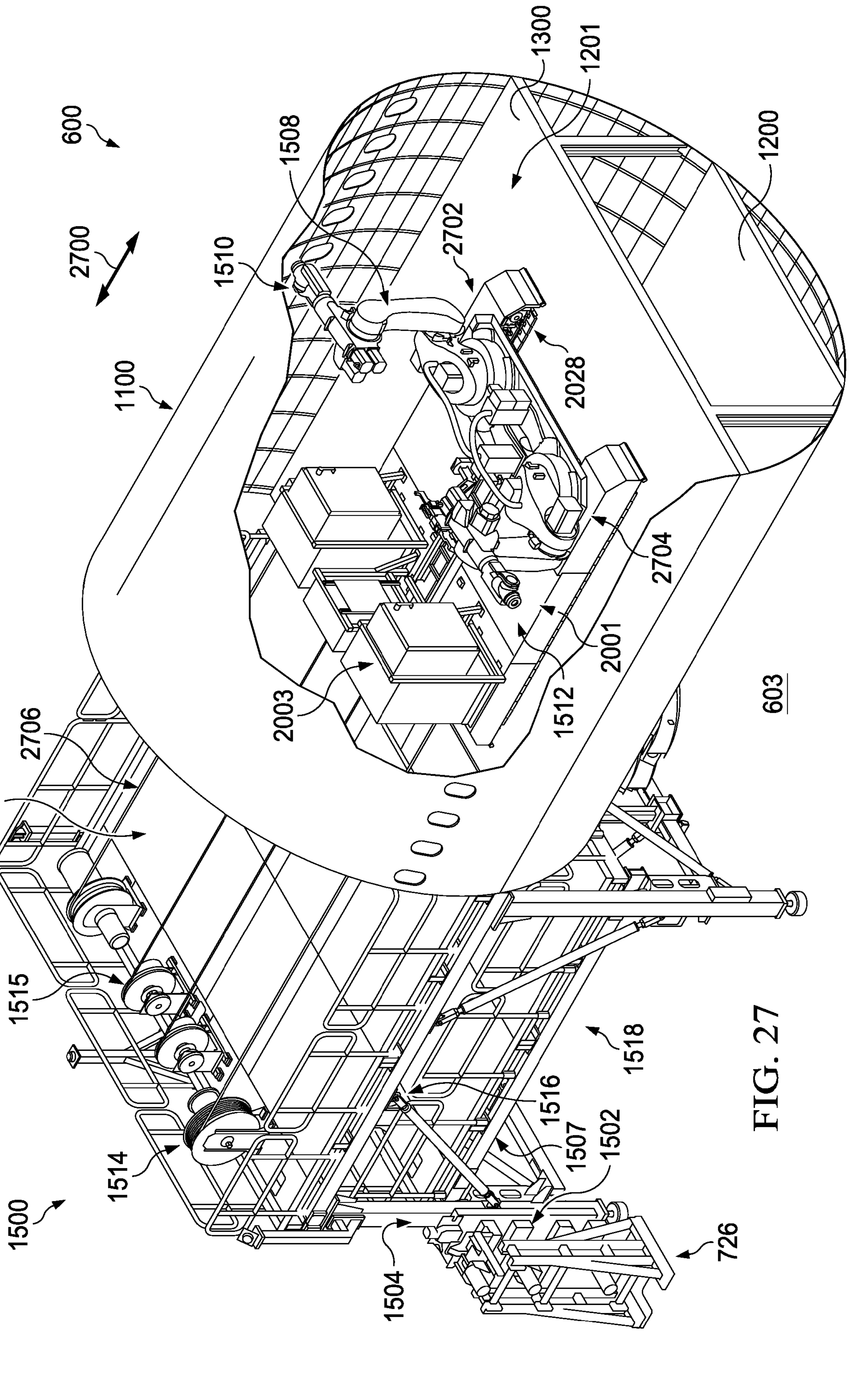

600
2700
1100
1510
1508
2702
1300
1201
1200
2028
2704
2001
1512
2003
603
2706
1506
1515
1514
1500
1518
1516
1507
1502
1504
726

FIG. 27

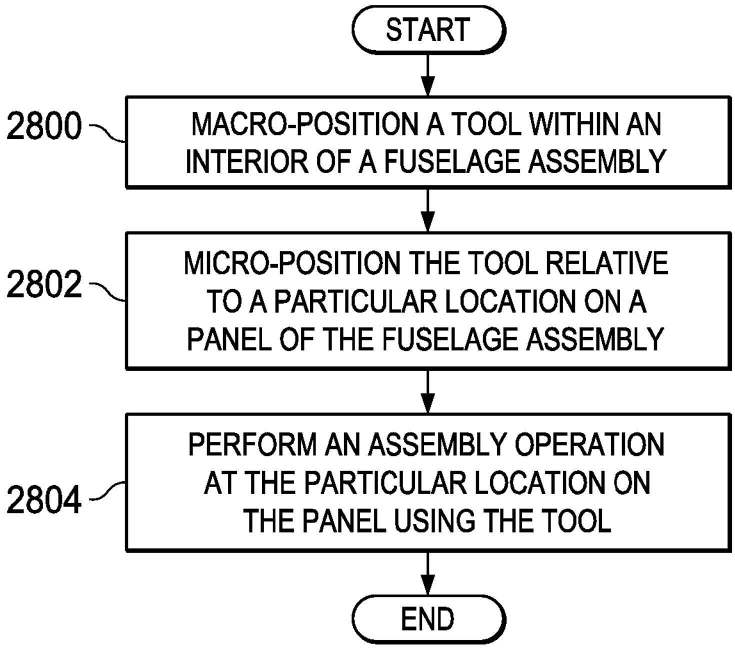

START
2800
MACRO-POSITION A TOOL WITHIN AN INTERIOR OF A FUSELAGE ASSEMBLY
2802
MICRO-POSITION THE TOOL RELATIVE TO A PARTICULAR LOCATION ON A PANEL OF THE FUSELAGE ASSEMBLY
2804
PERFORM AN ASSEMBLY OPERATION AT THE PARTICULAR LOCATION ON THE PANEL USING THE TOOL
END

FIG. 28

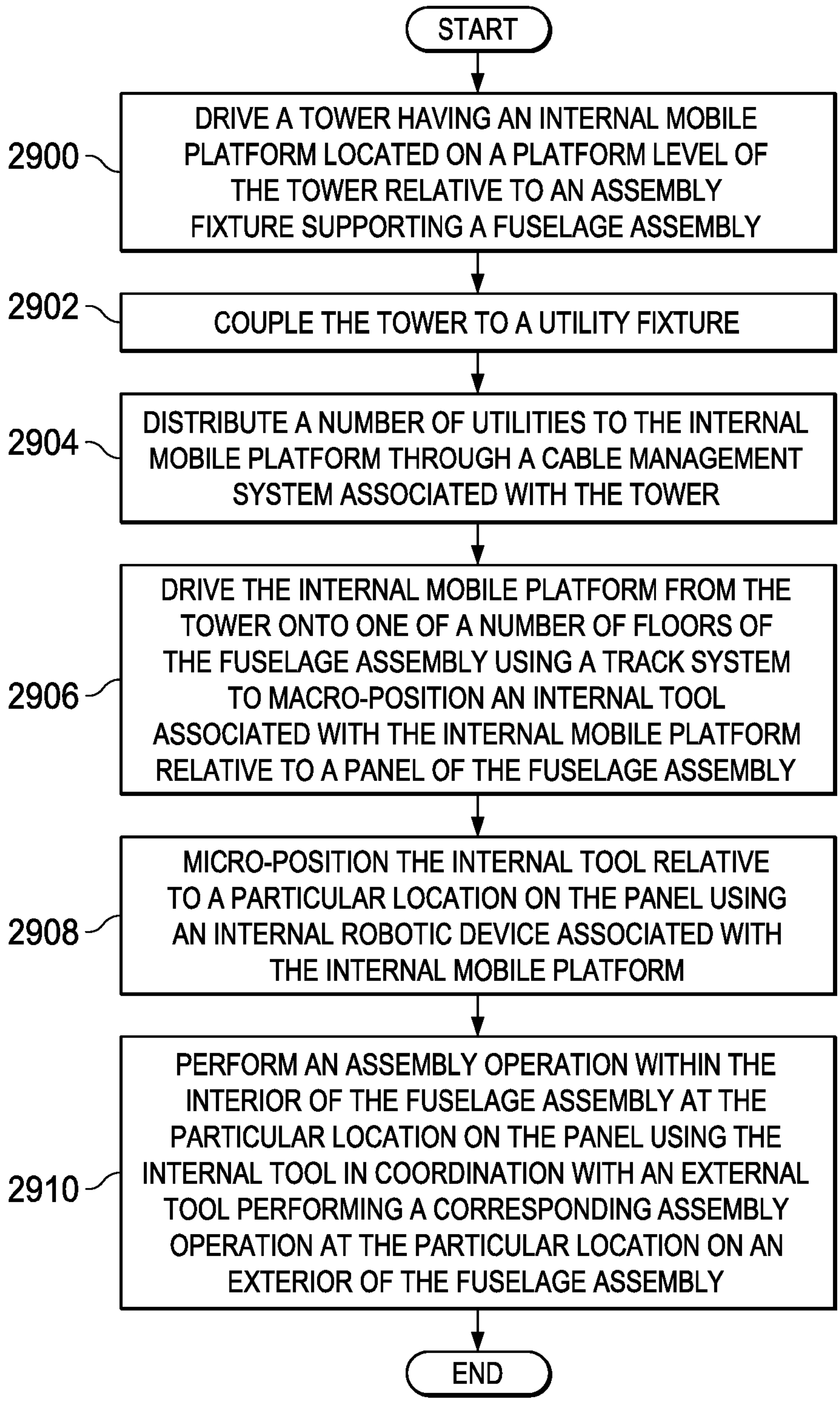

START
2900
DRIVE A TOWER HAVING AN INTERNAL MOBILE PLATFORM LOCATED ON A PLATFORM LEVEL OF THE TOWER RELATIVE TO AN ASSEMBLY FIXTURE SUPPORTING A FUSELAGE ASSEMBLY
2902
COUPLE THE TOWER TO A UTILITY FIXTURE
2904
DISTRIBUTE A NUMBER OF UTILITIES TO THE INTERNAL MOBILE PLATFORM THROUGH A CABLE MANAGEMENT SYSTEM ASSOCIATED WITH THE TOWER
2906
DRIVE THE INTERNAL MOBILE PLATFORM FROM THE TOWER ONTO ONE OF A NUMBER OF FLOORS OF THE FUSELAGE ASSEMBLY USING A TRACK SYSTEM TO MACRO-POSITION AN INTERNAL TOOL ASSOCIATED WITH THE INTERNAL MOBILE PLATFORM RELATIVE TO A PANEL OF THE FUSELAGE ASSEMBLY
2908
MICRO-POSITION THE INTERNAL TOOL RELATIVE TO A PARTICULAR LOCATION ON THE PANEL USING AN INTERNAL ROBOTIC DEVICE ASSOCIATED WITH THE INTERNAL MOBILE PLATFORM
2910
PERFORM AN ASSEMBLY OPERATION WITHIN THE INTERIOR OF THE FUSELAGE ASSEMBLY AT THE PARTICULAR LOCATION ON THE PANEL USING THE INTERNAL TOOL IN COORDINATION WITH AN EXTERNAL TOOL PERFORMING A CORRESPONDING ASSEMBLY OPERATION AT THE PARTICULAR LOCATION ON AN EXTERIOR OF THE FUSELAGE ASSEMBLY
END

FIG. 29

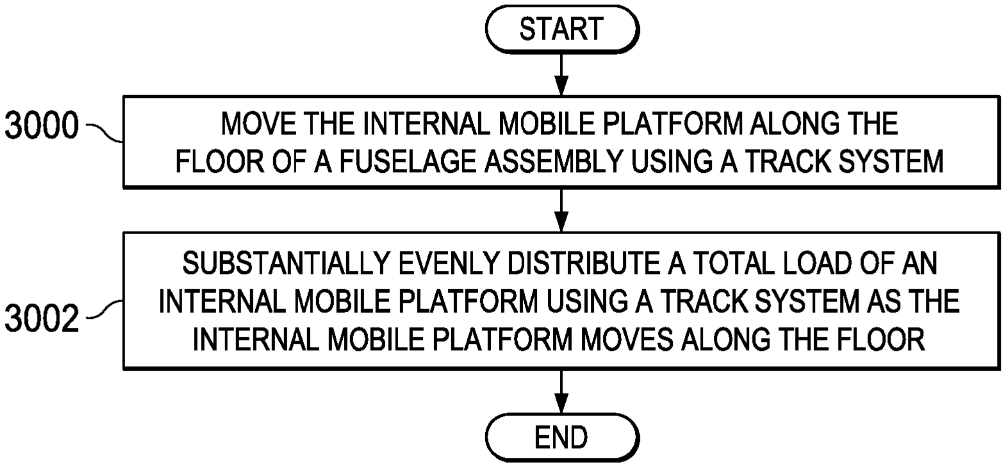

START
3000
MOVE THE INTERNAL MOBILE PLATFORM ALONG THE FLOOR OF A FUSELAGE ASSEMBLY USING A TRACK SYSTEM
3002
SUBSTANTIALLY EVENLY DISTRIBUTE A TOTAL LOAD OF AN INTERNAL MOBILE PLATFORM USING A TRACK SYSTEM AS THE INTERNAL MOBILE PLATFORM MOVES ALONG THE FLOOR
END

FIG. 30

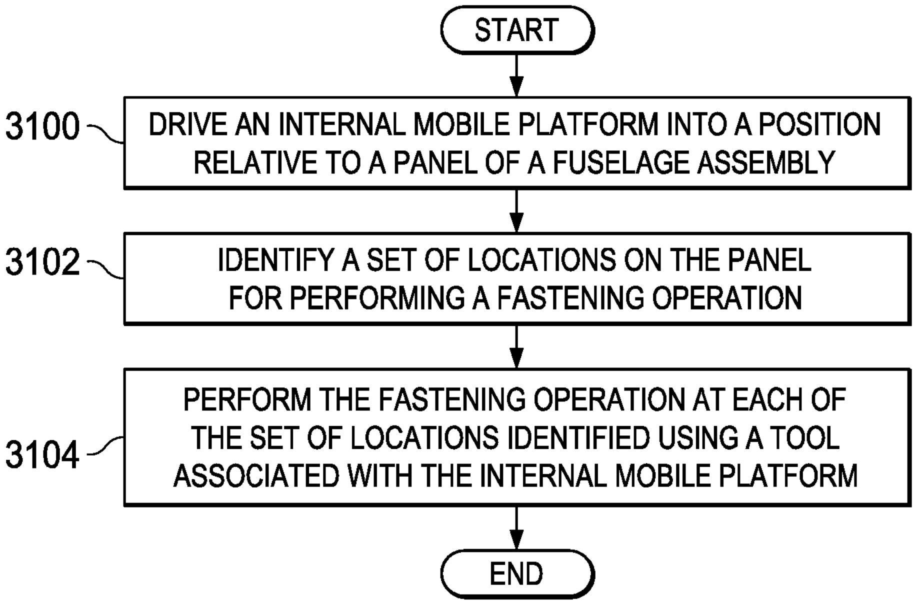

START
3100
DRIVE AN INTERNAL MOBILE PLATFORM INTO A POSITION RELATIVE TO A PANEL OF A FUSELAGE ASSEMBLY
3102
IDENTIFY A SET OF LOCATIONS ON THE PANEL FOR PERFORMING A FASTENING OPERATION
3104
PERFORM THE FASTENING OPERATION AT EACH OF THE SET OF LOCATIONS IDENTIFIED USING A TOOL ASSOCIATED WITH THE INTERNAL MOBILE PLATFORM
END

FIG. 31

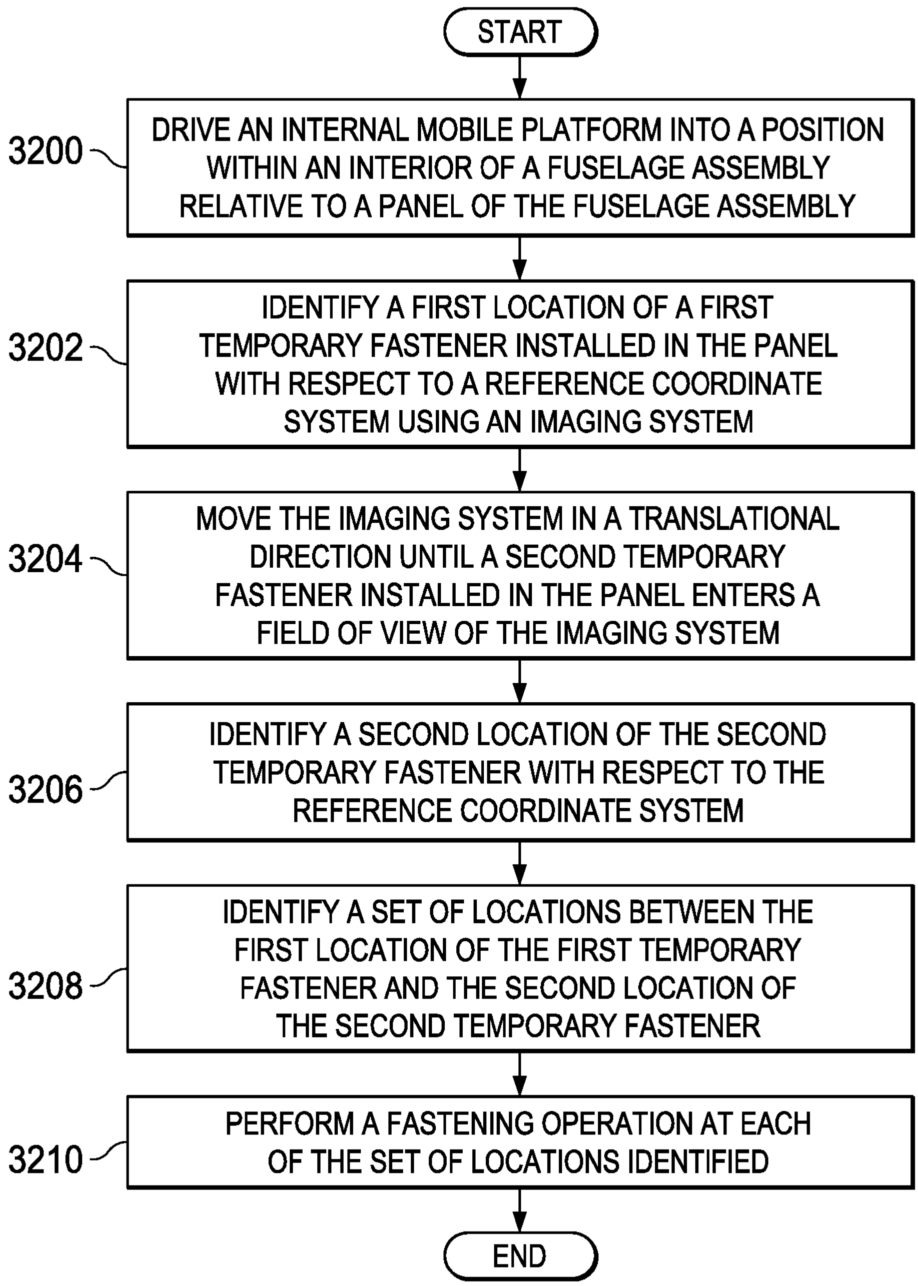

START
3200
DRIVE AN INTERNAL MOBILE PLATFORM INTO A POSITION WITHIN AN INTERIOR OF A FUSELAGE ASSEMBLY RELATIVE TO A PANEL OF THE FUSELAGE ASSEMBLY
3202
IDENTIFY A FIRST LOCATION OF A FIRST TEMPORARY FASTENER INSTALLED IN THE PANEL WITH RESPECT TO A REFERENCE COORDINATE SYSTEM USING AN IMAGING SYSTEM
3204
MOVE THE IMAGING SYSTEM IN A TRANSLATIONAL DIRECTION UNTIL A SECOND TEMPORARY FASTENER INSTALLED IN THE PANEL ENTERS A FIELD OF VIEW OF THE IMAGING SYSTEM
3206
IDENTIFY A SECOND LOCATION OF THE SECOND TEMPORARY FASTENER WITH RESPECT TO THE REFERENCE COORDINATE SYSTEM
3208
IDENTIFY A SET OF LOCATIONS BETWEEN THE FIRST LOCATION OF THE FIRST TEMPORARY FASTENER AND THE SECOND LOCATION OF THE SECOND TEMPORARY FASTENER
3210
PERFORM A FASTENING OPERATION AT EACH OF THE SET OF LOCATIONS IDENTIFIED
END

FIG. 32

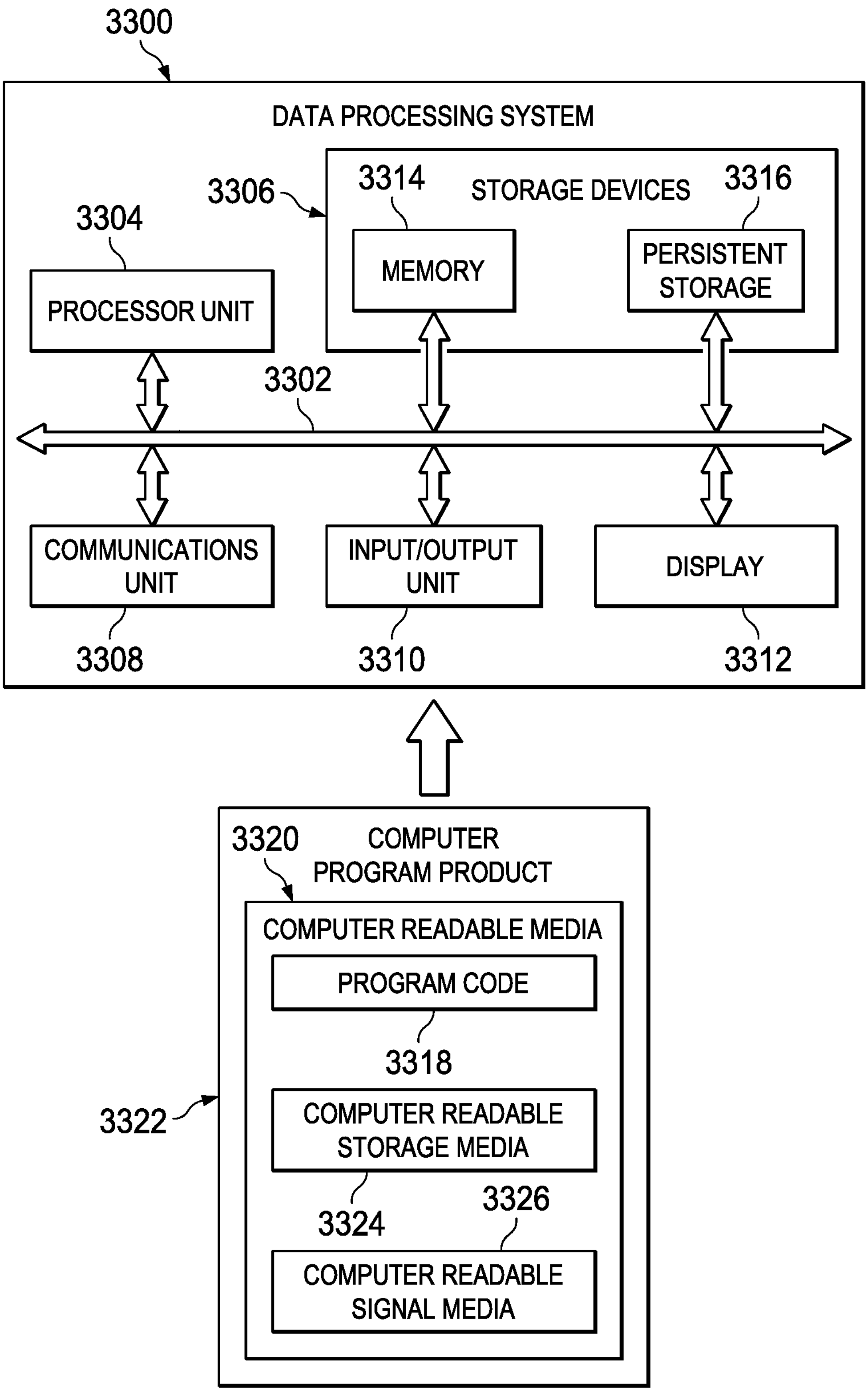

3300
DATA PROCESSING SYSTEM
3306
3314
STORAGE DEVICES
3316
3304
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
3302
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
3308
3310
3312
3320
COMPUTER PROGRAM PRODUCT
COMPUTER READABLE MEDIA
PROGRAM CODE
3318
3322
COMPUTER READABLE STORAGE MEDIA
3324
3326
COMPUTER READABLE SIGNAL MEDIA

FIG. 33

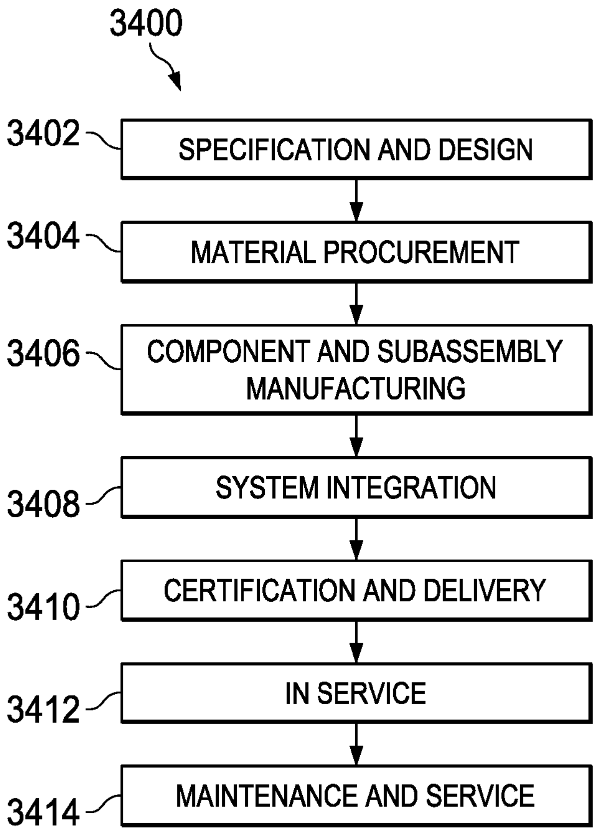

3400
3402
SPECIFICATION AND DESIGN
3404
MATERIAL PROCUREMENT
3406
COMPONENT AND SUBASSEMBLY MANUFACTURING
3408
SYSTEM INTEGRATION
3410
CERTIFICATION AND DELIVERY
3412
IN SERVICE
3414
MAINTENANCE AND SERVICE

FIG. 34

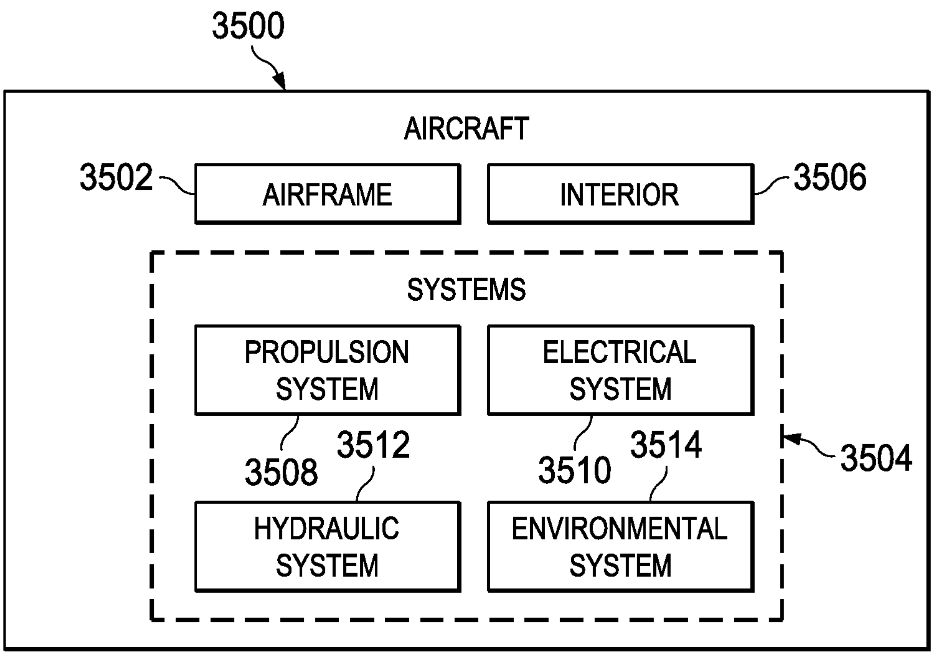

3500
AIRCRAFT
3502
AIRFRAME
INTERIOR
3506
SYSTEMS
PROPULSION SYSTEM
ELECTRICAL SYSTEM
3508
3512
3510
3514
3504
HYDRAULIC SYSTEM
ENVIRONMENTAL SYSTEM

FIG. 35

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6098260 A **[0006]**
- US 2012300093 A **[0007]**
- EP 2617536 A **[0008]**
- US 20120237319 A **[0009]**